California Environmental Protection Agency

Regional Water Quality Control Board
Central Valley Region

Draft
San Joaquin River Diazinon and Chlorpyrifos
Total Maximum Daily Load Report

July 2002

State of California

California Environmental Protection Agency

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

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CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

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List of Acronyms and Abbreviations

§	Section (as in a law or regulation)
Σ	Sum
µg/L	Micrograms/liter (0.10 ì g/L = 100 ng/L)
a.i.	Active ingredient of a pesticide
Basin Plan	Water Quality Control Plan (Basin Plan) Central Valley Region ; Sacramento River and San Joaquin River Basins
CCC	Criterion Continuous Concentration
CDEC	California Data Exchange Center
CDFG	California Department of Fish and Game
CMC	Criterion Maximum Concentration
CVRWQCB	Central Valley Regional Water Quality Control Board
CWA	Federal Clean Water Act
CWC	California Water Code
Delta	Sacramento-San Joaquin Delta
DPR	California Department of Pesticide Regulation
DWR	California Department of Water Resources
ELISA	Enzyme-linked immunosorbent assays
g/day	Grams/day
in.	Inches
LA	Load allocation
lbs	Pounds
LC	Loading capacity
LOQ	Limit of quantification
MOS	Margin of safety
NCDC	National Climatic Data Center
ng/L	Nanograms/liter (100 ng/L = 0.10 ì g/L)
NWIS	National Water Information System
Porter-Cologne or Porter-Cologne Act	Porter-Cologne Water Quality Control Act as amended
ppm	Parts per million
PUR	Pesticide Use Report
State Board or SWRCB	California State Water Resources Control Board
SWDB	Surface Water Database
TIE	Toxicity Identification Evaluation

List of Acronyms and Abbreviations

TMDL	Total Maximum Daily Load
UCIPM	University of California Statewide Integrated Pest Management Project
USDA	United States Department of Agriculture
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	Waste Load Allocation
WDRs	Waste Discharge Requirements

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EXECUTIVE SUMMARY

Water Body: Lower San Joaquin River

Project Area: Lower San Joaquin River downstream of the Mendota Dam to Airport Way Bridge near Vernalis.

Pollutant (s) Addressed: Chlorpyrifos and Diazinon

Extent of Impairment: Lower San Joaquin River, 130 river miles from Mendota Dam to the Airport Way Bridge near Vernalis.

Beneficial Uses for Surface Water: Municipal and domestic supply, agricultural supply, industrial supply, contact and non-contact water recreation, freshwater aquatic habitat, fish migration, fish spawning, and wildlife habitat.

Environmental Characteristics: The San Joaquin River (SJR) watershed is bound by the Sierra Nevada Mountains on the east, the Coast Ranges on the west, the Delta to the north, and the Tulare Lake Basin to the south. From its source in the Sierra Nevada Mountains, the SJR flows southwesterly until it reaches Friant Dam. Downstream of Friant Dam, the SJR flows westerly to the center of the San Joaquin Valley near Mendota, where it turns northwesterly to join the Sacramento River in the Delta. The main stem of the SJR has a length of about 300 miles and drains an area of about 13,500 square miles. Runoff from rain events occurring in the San Joaquin Valley provides short-term increases in river discharge and a mechanism for off-site movement of pesticides. River discharge during the summer is composed of dam releases of snow-melt water for agricultural, urban, recreational, and wildlife purposes, and irrigation return flows.

The SJR is a major tributary of the Sacramento-San Joaquin Delta (Delta) that drains approximately 8.7-million acres in California's Central Valley. The LSJR watershed is located in portions of Stanislaus, Madera, Merced, San Joaquin, and Fresno Counties. The project area for the TMDL encompasses approximately 2.9 million acres and agriculture is the predominant land use (1.9 million acres).

The lower San Joaquin River (LSJR) is listed on the Federal Clean Water Act's 303(d) list as impaired for diazinon and chlorpyrifos. The impairment extends from downstream of the Mendota Pool to the Airport Way Bridge near Vernalis. The 303(d) listing requires development of a Total Maximum Daily Load (TMDL) for diazinon and chlorpyrifos in the LSJR. This TMDL has been developed to: 1) identify the major sources of diazinon and chlorpyrifos loading to the LSJR; 2) determine the allowable loads of diazinon and chlorpyrifos that may occur while still meeting water quality objectives; and 3) equitably allocate these allowable loads to identified sources. The major components of the TMDL are a problem statement, numeric targets, a source analysis, load allocations and linkage analysis.

The Central Valley Regional Water Quality Control Board is currently in the process of preparing an amendment to the Water Quality Control Plan for the Central Valley (Basin plan) to establish diazinon and chlorpyrifos water quality objectives. There are currently no numeric water quality objectives for diazinon or chlorpyrifos in the SJR. The targets selected for this TMDL will be proposed as new water quality objectives as part of the TMDL implementation and Basin Plan Amendment process.

The TMDL has shown that sources of diazinon and chlorpyrifos are widely distributed in the TMDL project area. There are measurable concentrations of diazinon and chlorpyrifos in both the dormant and irrigation season and the proposed targets are exceeded in the LSJR in both seasons.

Total allowable loads have been calculated for diazinon and chlorpyrifos for the dormant and irrigation seasons assuming a one in three year excursion rate of the numeric targets for each season. These "one in three year" loads assume that targets will not be exceeded in the other season. Allowable loads are also presented assuming two seasons of use and target excursions using a one in six year excursion rate. To comply with targets in both seasons, the "one in six year" loads for each season are lower than the "one in three year" loads. Finally, allowable loads assume the presence of only one pesticide, diazinon or chlorpyrifos. In consideration of the additive toxic effects of diazinon and chlorpyrifos, these allowable loads must be further reduced to account for the presence of the other pesticide. Allowable loads of diazinon and chlorpyrifos, assuming one season of use, are presented in tables 4.9 and 4.10, respectively. Allowable loads of diazinon and chlorpyrifos, assuming two seasons of use, are presented in tables 4.13 and 4.14, respectively. Allowable loads are presented for six reaches of the LSJR based on the variable hydrology of these reaches.

No waste load allocations are provided for point sources in this TMDL. All allowable loads are allocated to agricultural sources using two scenarios: a purely geographic allocation, and; a crop-based geographic allocation. Load allocations based on only one season of use and target excursion (one in three year excursion rate) are presented in table 5.13. Load allocations based on two seasons of use and target excursion (one in six year excursion rate) are presented in table 5.14.

1.0 INTRODUCTION AND PROBLEM STATEMENT

The lower San Joaquin River (LSJR) is listed on the Federal Clean Water Act's 303(d) list as impaired for diazinon and chlorpyrifos. The impairment extends from downstream of the Mendota Pool to the Airport Way Bridge near Vernalis. The 303(d) listing requires development of a Total Maximum Daily Load (TMDL) for diazinon and chlorpyrifos in the LSJR. This TMDL has been developed to: 1) identify the major sources of diazinon and chlorpyrifos loading to the LSJR; 2) determine the maximum amount of diazinon and chlorpyrifos loading that occur while still meeting water quality objectives; and 3) equitably allocate the available assimilative capacity among the identified sources. This introduction and problem statement provide the regulatory and technical background for the TMDL.

1.1 Regulatory Background

The Federal Clean Water Act requires states to develop TMDLs for waterbodies that are not attaining water quality standards. The state Porter-Cologne Water Quality Control Act (Porter-Cologne) gives each of the California Regional Water Quality Control Boards (Regional Boards) the authority to develop water quality control programs and establish the water quality objectives needed to implement TMDLs.

Clean Water Act 303(d) Listing and Total Maximum Daily Load Development

Section 303(d) of the federal Clean Water Act requires States to:

- Identify those waters not attaining water quality standards and place on 303(d) list of impaired waterbodies (303(d) list).
- Set priorities for addressing the identified pollution problems.
- Establish a "Total Maximum Daily Load" (TMDL) for each identified waterbody and pollutant to attain water quality standards.

The 303(d) list for the Central Valley is prepared by the Regional Board and approved by the State Water Resources Control Board (State Board) and the US Environmental Protection Agency (EPA). Waterbodies on the 303(d) list are not expected to meet water quality standards even if point source dischargers comply with their current discharge permit requirements. A TMDL represents the maximum load (usually expressed as a rate, such as grams per day [g/day] or pounds per day [lbs/day]) of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL describes the reductions needed to meet water quality standards and allocates those reductions among the sources in the watershed. A TMDL is defined as the sum of the individual waste load allocations (WLAs) from point sources, load allocations (LAs) from nonpoint sources, background loading (BL) and an appropriate margin of safety (MOS). Loading from all pollutant sources must not exceed a water bodies Loading Capacity (LC), the amount of pollutant loading that a water body can receive without violating Water Quality Objectives. That is,

$$TMDL = LC = \sum WLA + \sum LA + MOS$$

Where Σ = the sum, LC = loading capacity, WLA = waste load allocations, LA = load allocations (including load allocations for natural and background sources) and MOS = a margin of safety.

Elements of a TMDL include:

- Problem statement
- Numerical water quality target or targets
- Identification and quantification of sources and source loads
- Maximum allowable load of the contaminant that will not adversely impact beneficial uses and the mathematical linkage analysis that describes the relationship between the water quality target and loading capacity
- Allocation of portions of the necessary load reduction to the various sources and contaminant
- Margin of safety that takes into account uncertainties and consideration of seasonal variations.

Porter-Cologne Water Quality Control Act

The Porter-Cologne Water Quality Control Act, which is contained in Division 7 of the California Water Code (CWC), establishes the responsibilities and authorities of the Regional Water Quality Control Board (Regional Board), including authority and responsibility for regional water quality control and planning. The Regional Board establishes water quality objectives and programs to implement those objectives by amending the Central Valley Region's Water Quality Control Plan for the Sacramento and San Joaquin River Basins (Basin Plan). Changes in regulation will occur when elements of TMDLs are incorporated into the Basin Plan through the Basin Plan Amendment process.

Basin Plan Amendment Process

In general, the Regional Board will develop a water quality management strategy for each waterbody and pollutant in the Central Valley identified on California's 303(d) List. The management strategy will include several phases:

- TMDL Development: technical analysis of the sources of pollutant(s), the fate and transport of those pollutants, the numeric target(s), the allowable amount of pollutant load that will attain the target, and the allocation of the allowable load among sources of the pollutant(s).

- Implementation Planning: evaluation of the practices and technology that can be applied to meet the necessary load reductions, the identification of potentially responsible parties, a description of the implementation framework (e.g. incentive-based, waste discharge requirements, and prohibitions), a time schedule for meeting the target(s), and a consideration of cost.
- Basin Planning: development of a Basin Plan Amendment and a Functionally Equivalent Document for Regional Board consideration. The Basin Plan Amendment will include those policies and regulations that the Regional Board believes are necessary to attain water quality objectives. The Functionally Equivalent Document includes information and analyses required to comply with the California Environmental Quality Act.

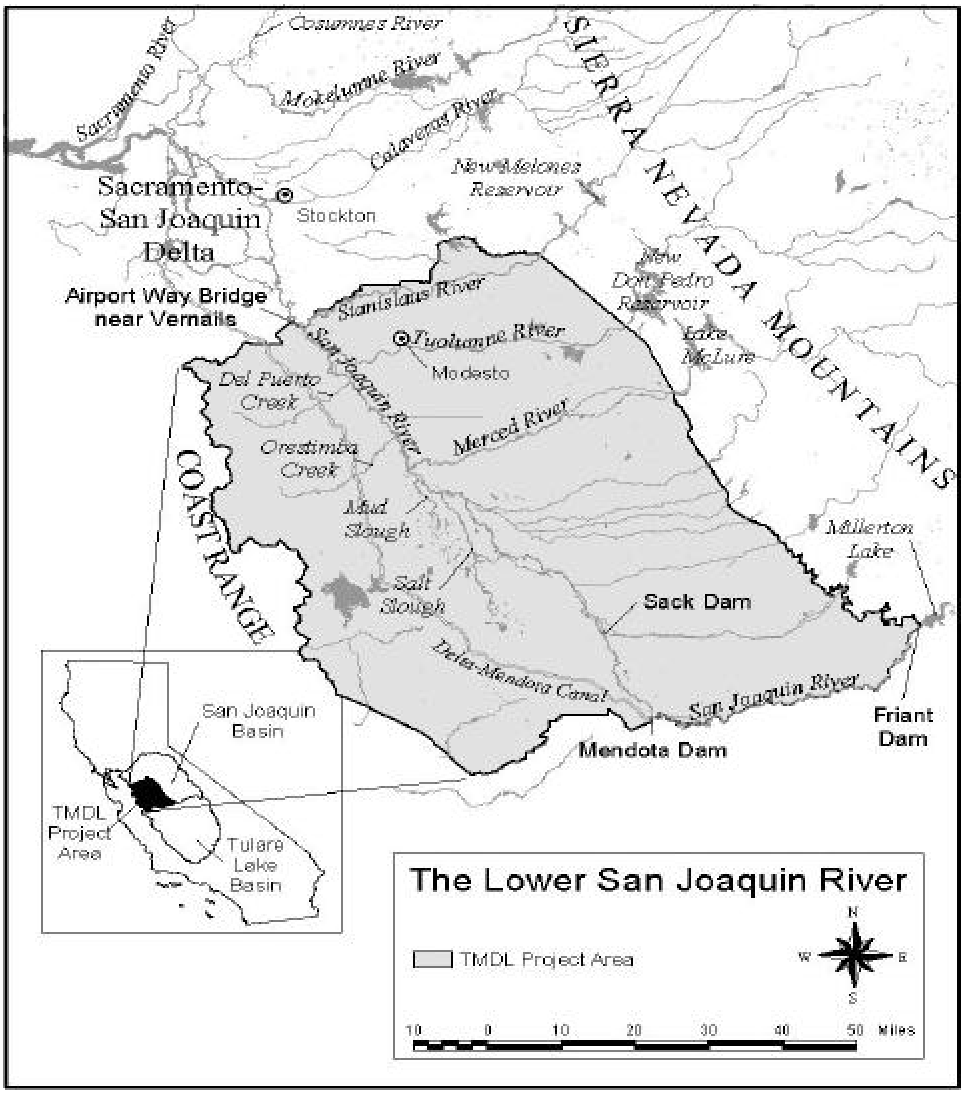
In general, the water quality management strategy presented to the Regional Board will include water quality objectives and a program of implementation (§13241 and §13242 of the Porter-Cologne Water Quality Act), including those elements necessary to meet federal TMDL requirements (CWA Section 303(d)). The Basin Plan Amendment is legally applicable once it is approved by the Regional Board, State Board, Office of Administrative Law and the USEPA.

1.2 Watershed Setting and TMDL Scope

The geographic scope of this TMDL is the LSJR downstream of the Mendota Dam to the Airport Way near Vernalis. The LSJR Watershed is defined as the area draining to the SJR downstream of the Mendota Dam and upstream of Vernalis. For TMDL planning and analysis purposes, the LSJR watershed excludes areas upstream of the dams of major eastside reservoirs of New Don Pedro, New Melones, and Lake McClure or similar eastside reservoirs in the LSJR system. The main stem of the entire SJR is about 300 miles long and drains approximately 13,500 square miles. (Figure 1-1).

Diazinon and chlorpyrifos are broad spectrum, organophosphorus pesticides used for urban and agricultural pest control in the LSJR Watershed. The LSJR is currently listed on the Central Valley Region's 303(d) list as impaired for diazinon and chlorpyrifos. This report presents the results of the TMDL development phase for diazinon and chlorpyrifos in the LSJR and contains all of the elements of a TMDL listed in Section 1-1, above. This report is being developed concurrently with an Implementation Plan report. When complete, this report and the Implementation Plan report will be used for developing a Basin Plan Amendment Staff Report and a proposed Basin Plan Amendment during the Basin Planning phase.

Figure 1.1 Location Map



1.3 Problem Statement

The purpose of the problem statement is to provide the context and background for the TMDL and to describe the water quality impairments being addressed. This problem statement describes the water body segments and pollutants being addressed by the TMDL, the relevant water quality standards, and the basis for the 303(d) listings. It alos provides an overview of the environmental characteristics, hydrology and land uses of the watershed.

Environmental Characteristics

The southern part of the Central Valley of California is comprised of two hydrologic basins: the San Joaquin River and the Tulare Lake Basins. The SJR drains the SJR Basin, which discharges to the Sacramento-San Joaquin Delta (the Delta). The Tulare Lake Basin is for the most part an internal hydrologically closed drainage basin that occasionally overflows into the SJR Basin during extremely high flood flow periods. Otherwise, these watersheds have separate drainages.

The LSJR watershed is bound by the Sierra Nevada Mountains on the east, the Coast Range on the west, the Delta to the north, and the Tulare Lake Basin to the south. From its source in the Sierra Nevada Mountains, the SJR flows southwesterly until it reaches Friant Dam. Downstream of Friant Dam, the SJR flows westerly to the center of the San Joaquin Valley near Mendota, where it turns northwesterly to join the Sacramento River in the Delta. The main stem of the SJR has a length of about 300 miles and drains an area of about 13,500 square miles.

Major tributaries to the SJR are on the east side of the San Joaquin Valley, with drainage basins in the Sierra Nevada Mountains. These major east side tributaries are the Stanislaus, Tuolumne, and Merced Rivers. The Consumnes, Mokelumne, and Calaveras Rivers flow into the SJR downstream of Vernalis in the Delta. Several smaller, ephemeral streams flow into the SJR from the west side of the valley. These streams include Hospital, Ingram, Del Puerto, Orestimba, San Luis, and Los Banos Creeks. All have drainage basins in the Coast Range, flow intermittently, and contribute sparsely to water supplies. Mud Slough (north) and Salt Slough also drain the Grassland Watershed on the west side of San Joaquin Valley. During the irrigation season, surface and subsurface agricultural return flows contribute greatly to these creeks and sloughs.

Land Use

The San Joaquin Valley occupies approximately 18 million acres in the southern portion of California's Central Valley, accounting for almost 18 percent of the total land area of the state. The San Joaquin Valley is one of the most important agricultural areas in the United States. Most of the valley floor is agricultural land, and its agricultural history dates back to the 1870s. In 1987, California produced 10.2 percent of the total value of agricultural production in the United States, 40 percent of which was generated in the San Joaquin Valley (San Joaquin Valley Drainage Program, 1990). Urban areas within the LJSR watershed are expanding and the population of the 13 largest cities in the LSJR watershed increased an average of 1.5 percent between 1998 and 1999 (CADF, 1999). Modesto is the largest city in the LJSR watershed, with a current population about 184,600. Other large urban areas in the LJSR watershed include the cities of Merced (pop. 62,800), Turlock (pop. 51,900), Ceres (pop. 32,400), Atwater (pop. 22,250), and Los Banes (pop. 22,200).

The San Joaquin Valley is also known for its high natural resource values. It is estimated that the San Joaquin Valley once contained about 1.1 million acres of permanent and seasonal wetlands, with approximately 731,000 acres in San Joaquin Basin and 360,000 acres in the Tulare Basin. Prior to major water developments, the San Joaquin River watershed supported a Chinook salmon fishery and tens of thousands of salmon probably spawned in its headwaters (SWRCB, 1987). However, steady decline of fish and wildlife habitat have occurred in connection with large-scale agricultural, urban and water development. Approximately 92 percent of the historic seasonal and permanent wetlands in the San Joaquin Valley have been drained and reclaimed for agricultural purposes (San Joaquin Drainage Program, 1990). Table 1.1 lists agricultural and urban land use in the San Joaquin Valley based on standard land use legend by the State of California Department of Water Resources (DWR) (DWR, 1994-1996).

Table 1.1 Agricultural and Urban Land Use in San Joaquin River Valley.

Agricultural Land Use	Area (acres)
Citrus and Subtropical	8,016
Deciduous Fruits and Nuts	357,504
Field Crops	425,470
Grain and Hay Crops	88,197
Idle Land	364
Pasture	300,455
Rice	12,827
Truck, Nursery, and Berry Crops	105,054
Vineyards	126,937
Semiagricultural	515
Total Agriculture	1,425,339
Total Urban	130,862

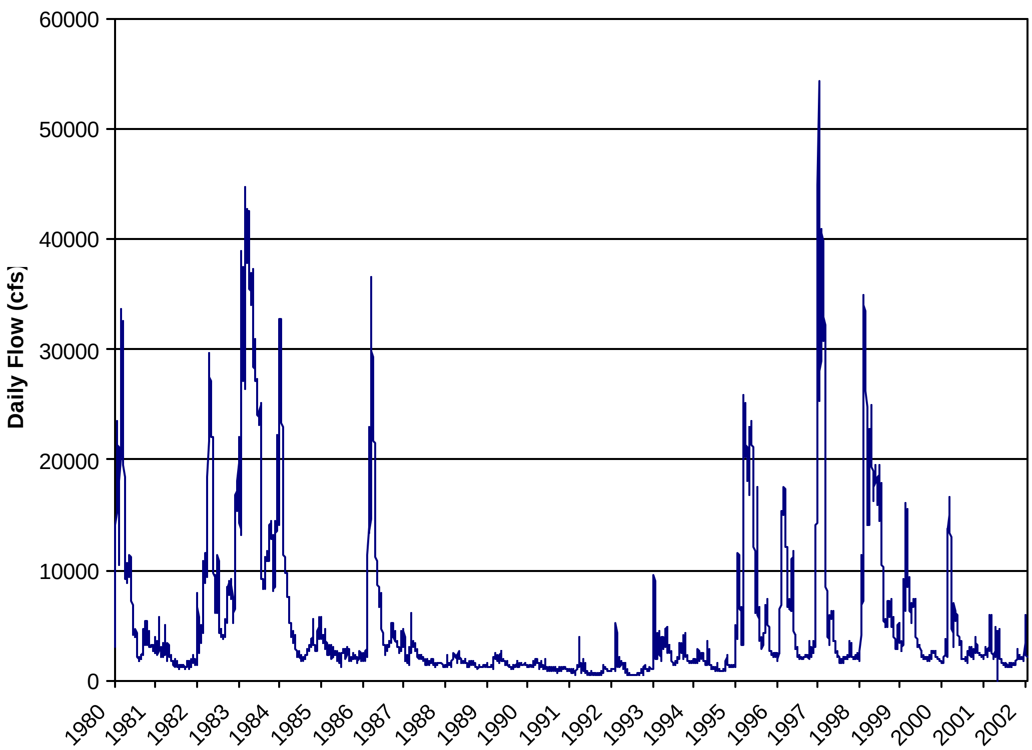
Hydrology

Precipitation is unevenly distributed throughout the SJR Basin. About 90 percent of the precipitation falls during the months of November through April. Normal annual precipitation ranges from an average of eight inches on the valley floor (in the trough of the basin) to about seventy inches at the headwaters in the Sierra Nevada. Precipitation at the higher elevations primarily occurs as snow. Potential evaporation on the valley floor is over 50 inches annually.

The hydrology of the SJR is complex and highly managed through the operation of dams, diversions, and supply conveyances. Water development has effectively fragmented the watershed and severely altered the natural hydrograph of the river. Runoff from the Sierra Nevada and foothills is regulated and stored in a series of reservoirs on the east side of the SJR. There are 57 major reservoirs in the basin that have the capacity to store over 1,000 acre-feet of water; four of these can store over 1,000,000 acre-feet each. Friant Dam (Millerton Lake) on the main stem of the upper SJR, which was built in 1942, has a capacity of just over 500,000 acre-feet. These and other reservoirs control flow and by doing so greatly influence the water quality of the LSJR by seasonally releasing little water to provide dilution capacity for pollutants.

Most of the natural flows from the Upper SJR and its headwaters are diverted at the Friant Dam to the Tulare Lake Basin via the Friant-Kern Canal. This leaves much of the river dry between Friant Dam and the Mendota Pool except during periods of wet weather flow and major snow melt. Water is imported to the basin from the south Delta via the Delta Mendota Canal (DMC) to replace the flows that are diverted out of the basin to the south. Annual discharge in the SJR near Vernalis from 1980 to 2002 is shown in Figure 1.2

Figure 1.2 Annual Average Discharge for Lower San Joaquin River near Vernalis (1980-2002)



Beneficial Uses and Water Quality Standards

The SJR Basin Plan was developed to protect surface water and groundwater quality throughout these basins. The Basin Plan designates beneficial uses for each water body within the Region, and water quality objectives to protect these uses. The Basin Plan also contains implementation programs to achieve and maintain compliance with water quality objectives. For surface waters, beneficial use designations and water quality objectives constitute water quality standards under the Federal Clean Water Act.

Beneficial Uses

The San Joaquin River has a multitude of beneficial uses, including domestic and agricultural water supply, aquatic habitat, and recreational opportunities. Table 1.2 lists the beneficial uses for surface water in LSJR.

Table 1.2 Lower San Joaquin River Beneficial Uses

	MUN	*AGR*		*PROC*	*REC-1*		*REC-2*	*WARM*	*COLD*	*MIGR*		*SPWN*		*WILD*
LOWER SAN JOAQUIN RIVER REACH	*MUNICIPAL AND DOMESTIC SUPPLY*	*IRRIGATION*	*STOCK WATERING*	*INDUSTRIAL PROCESS*	*CONTACT*	*CANOEING AND RAFTING*	*OTHER NONCONTACT*	*FRESHWATER HABITAT-WARM*	*FRESHWATER HABITAT-COLD*	*WARM*	*COLD*	*WARM*	*COLD*	*WILDLIFE HABITAT*
MENDOTA DAM TO SACK DAM	*P*	*E*	*E*	*E*	*E*	*E*	*E*	*E*		*E*	*E*	*E*	*P*	*E*
SACK DAM TO MERCED RIVER	*P*	*E*	*E*	*E*	*E*	*E*	*E*	*E*		*E*	*E*	*E*	*P*	*E*
MERCED RIVER TO VERNALIS	*P*	*E*	*E*	*E*	*E*	*E*	*E*	*E*		*E*	*E*	*E*		*E*

E: Existing, P: Potential, MUN: Municipal, AGR: Agriculture, PROC: Process, REC: Recreation, MIGR: Migration

Water Quality Objectives

Water quality objectives in the current Basin Plan that are relevant to diazinon and chlorpyrifos in SJR are summarized below.

Pesticides

The *Water Quality Objectives* section of the Basin Plan includes the following potentially applicable statement regarding pesticides in the subsection titled *Water Quality Objectives for Inland Surface Waters:*

- No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses
- Discharges shall not result in pesticide concentrations in bottom sediments or aquatic life that adversely affect beneficial uses
- Pesticide concentrations shall not exceed those allowable by applicable antidegradation policies
- Pesticide concentrations shall not exceed the lowest levels technically and economically achievable.

For purposes of these objectives, the term pesticide shall include: (1) any substance, or mixture of substances which is intended to be used for defoliating plants, regulating plant growth, or for preventing, destroying, repelling, or mitigating any pest, which may infest or be detrimental to vegetation, humans, animals, households, or be present in any agricultural or nonagricultural environment whatsoever, or (2) any spray adjuvant, or (3) any breakdown products of these materials that threaten beneficial uses. Note that discharges of "inert" ingredients included in pesticide formulations must comply with all applicable water quality objectives.

Toxicity

The narrative objective for pesticides states, "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider … numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective." (CRWQCB-CVR, 1998). The Regional Board has not established numerical water quality objectives for diazinon or chlorpyrifos. The California Department of Fish and Game (CDFG) has developed acute and chronic toxicity criteria for diazinon and chlorpyrifos (Siepmann and Finlayson, 2000), shown in Table 1.3 below, that was determined by using methods established by the US EPA for protection of aquatic life (US EPA, 1985).

Table 1.3 CDFG Freshwater Aquatic Life Criteria for Diazinon and Chlorpyrifos

	Criterion Values	Criterion Type	Criterion Recurrence Period
Diazinon	0.080 ì g/L	Acute, Criteria Maximum Concentration (CMC)	1-hour average; not to be exceeded more than once every 3 years
	0.050 ì g/L	Chronic, Criteria Continuous Concentration (CCC)	4-day average; not to be exceeded more than once every 3 years

	Criterion Values	Criterion Type	Criterion Recurrence Period
Chlorpyrifos	0.025 ì g/L	Acute, Criteria Maximum Concentration (CMC)	1-hour average; not to be exceeded more than once every 3 years
	0.014 ì g/L	Chronic, Criteria Continuous Concentration (CCC)	4-day average; not to be exceeded more than once every 3 years

Chemical and Physical Properties

The chemical and physical properties of diazinon and chlorpyrifos determine their fate and transport in the environment and potential exposure risks to aquatic life. Diazinon binds only moderately to soil and sediment, is moderately soluble in water, and has a low vapor pressure (0.64 mPa at 20º C). These properties imply that diazinon can generally readily migrate in surface water, and its low vapor pressure indicates a relatively low tendency to volatilize into air or fog (Giddings *et al.*, 2000). Diazinon rapidly degrades into the more persistent oxypyrimidine under aerobic, anaerobic, aquatic anaerobic and sterile soil conditions. Degradation of diazinon under sterile and anaerobic soil condition occurs by chemical hydrolysis in acidic soils. In water, diazinon is stable at pH 7 and pH 9, but hydrolyzes in non-sterile water at a pH of 5 (U.S.EPA, 1988), with a resulting half-life of 12 to 14 days. Under neutral or basic conditions, diazinon half-lives is reported to range from 54.6 to 138 days (Giddings *et al.*, 2000). However, under conditions of low temperature, low moisture, and high alkalinity, diazinon can remain in soils for greater than six months.

Chlorpyrifos is relatively insoluble in water and adsorbs strongly to soil organic matter (K_{OC} 5300 to 14800) indicating that chlorpyrifos is less likely than diazinon to become mobile in the environment. Chlorpyrifos is moderately volatile, with a vapor pressure of 2.3 mPa at 20º C, with volatilization primarily occurring from pond surfaces to pond sediments, where chlorpyrifos half-lives range from 14 to 64 days, and periodically longer time periods (Poletika and Robb, 1998). Like diazinon, the fate of chlorpyrifos in the environment is partially determined by microbial degradation and hydrolysis (at a constant of 0.0236 per day at pH 7). In soil and in surface applications, chlorpyrifos half-lives range from 33 to 56 days and 7 to 10 days, respectively (Fontaine *et al.*, 1987).

Biological Effects

Diazinon does not tend to bioconcentrate in most aquatic species; however, chronic and acute toxicological effects have been observed in several small freshwater invertebrates such as *Ceriodaphnia dubia*, a sensitive water flea test organism, when exposed to diazinon in the water column. (Foe and Sheipline, 1993). The reported 96-hour LC_{50}[1] values for *C. dubia* range from 410 to 470 ng/L (100ng/L = 0.10 ìg/L) (Bailey *et al.*, 1996) Other invertebrates show similar or more sensitivity to this compound. Other reported LC_{50} values are 210 ng/L for *Daphnia magna*, 200 ng/L for *Gammaraus fasciatus* and 30 ng/L for *Chironomus tentans* (Johnson and Finley, 1980; Mitchell, 1985; Morgan 1976).

In general aquatic arthropods also show the most sensitivity to chlorpyrifos. The reported 96-hour LC_{50} values for chlorpyrifos for *C. dubia* range from 52 to 60 ng/L (Bailey *et al.*, 1996) and an NOEC[2] of 40 ng/L (Bailey *et al., 1*996). Invertebrates indigenous to the region display comparable sensitivities, including a 96-hour LC_{50} of 70 and 160 ng/L for *Neomysis mercedis* (Bailey *et al*., 1996) and reproductive impairment for the invertebrate *Daphnia magna* at 80 ng/L (USEPA, 1985). It should be noted that when present in a mixture, these two compounds display additive toxicity (Bailey *et al*., 1996).

Sources and Effects in Water

There are both agricultural and urban sources of diazinon and chlorpyrifos in surface water of the SJR. Diazinon and chlorpyrifos are generally applied with dormant oil on nut and stone fruit trees to control pests, including peach twig borer and San Jose scale. The best time to achieve control of these pests is between December and February, when

[1] Lethal Concentration (LC)- exposure concentration that would result in death in a given percent of the test population. LC_{50} is the concentration of toxicant resulting in 50% mortality in a given period of time.

[2] No Observed Effect Concentration (NOEC)- the highest exposure concentration causing no observable adverse effects on the test organism.

trees are dormant and better pesticide coverage is possible (Zalom *et al*., 1995). The dormant orchard spray application period, however, coincides with seasonal rainfall. Thus, these pesticides are washed off the crops and migrate with runoff waters into the SJR and its tributaries. Chlorpyrifos is applied to orchards during the March to September irrigation season. Other major uses during the irrigation season are on alfalfa and sugarbeets for worm control, and on walnuts and almonds for codling moth and twig borer control (Foe and Sheipline, 1993).

Diazinon and chlorpyrifos use patterns in urban areas, including foundation and landscape applications, restaurant and building pest-control, use of animal-care products, and home fruit and vegetable gardens may contribute to the presence of these pesticides in surface water. During rainfall events, residual chlorpyrifos and diazinon have the potential to migrate with stormwater runoff and irrigation water from urban areas to tributaries that flow into the SJR. Finally, rainfall runoff can become contaminated by diazinon and chlorpyrifos far from the point of application due to volatilization of these pesticides into the atmosphere. During application, approximately 15-20% of liquid chlorpyrifos and diazinon can volatilize into the atmosphere. Volatilized OP pesticide particles can collect in condensed rain droplets that make their way back to the earth's surface waters far from the point of application (Hill, 1995). In air and water, UV radiation can change OP pesticides to more toxic compounds that can persist in the environment for 30 to 60 days.

Several recent studies report residues of OP pesticides in surface water of the SJR Basin of California (CRWQCB-CVR, 1995; USGS, 1995). Toxicity testing with the aquatic invertebrate Ceriodaphnia dubia indicates that surface water samples collected during different use seasons have the potential to cause adverse effects including acute mortality of aquatic organisms. Frequently, the samples shown to be acutely toxic to *Ceriodaphnia dubia* also contain OP insecticides at concentrations sufficient to account for the toxicity (Regional Water Quality Control Staff Report, 1995).

The concentration of OP pesticides that a given organism is exposed to and the organism's metabolism of the OP compounds and their metabolites determines potential toxicity to the affected organism. Although OP pesticides have a very short half-life (not persistent in the environment), do not biomagnify in food webs and are rapidly metabolized and/or excreted by most animals, they can be acutely toxic to invertebrates and vertebrates.

1.4 Monitoring Data

Data collected by several agencies for 1991 to 1998 have identified the occurance of diazinon and chlorpyrifos in the LSJR. This occurance has been linked to toxicity of aquatic life. The occurrence of these pesticides and their effect on the water quality of the SJR Basin has been studied by several agencies [U.S. Geological Survey (USGS), Regional Board, and Department of Pesticide Regulation]. Following is a summary of selected studies conducted in both agricultural and urban setting and during different use seasons A complete data set for chlorpyrifos and diazinon collected by various agencies from 1991 to 2002 is presented in Appendix A and B of the SJR Diazinon and Chlorpyrifos TMDL Source Analysis Report.

Regional Board staff conducted toxicity testing on samples collected in the SJR Basin from 1991 to 1996. The San Joaquin River near Vernalis was monitored daily for six days following storm events in 1994. A decrease in Electric Conductivity in the SJR near Vernalis suggested that the river contained high percentage of overland flow. Increased mortality and reduced reproduction was observed in the test species, *Ceriodaphnia dubia*, suggesting that overland flow contained chemicals responsible for the observed toxicity. Water samples collected on 27 January resulted in 100 % mortality in 72 hours to the test species. Toxicity Identification Evaluation (TIE) Phase I was conducted on water samples collected from Vernalis suggested the presence of a metabolically activated OP pesticides. During the Phase II TIE, toxicity was observed in the 80% fraction within 24 hours and in the 70 and 75% fractions within 72 hours. Diazinon is known to elute in the 75 and 80% fractions (Bailey *et al.*, 1996). Chemical analysis confirmed that diazinon was present at 0.5 μg/ l concentration and was the primary contaminant causing the toxicity. This detected concentration is greater than the 96 hour LC50 of *Ceriodaphnia dubia*.

Surface water samples also were collected from SJR near Vernalis in January and February 1996. Mortality of 100 percent was observed in water samples collected from the SJR near Vernalis on 28 January and 1 February. Complete mortality also was observed in water samples collected from this site on subsequent days. Phase 1 TIEs suggested the presence of a metabolically activated OP pesticide. Phase I, II and III TIEs also were conducted on samples collected on subsequent days. The results confirmed that diazinon was the main contaminant in each sample. Chemical analysis by USGS, DPR and Agricultural Priority Pollutant Laboratory confirmed that the samples contained diazinon at concentrations high enough to result in the observed toxicity (Foe, 1998). In one case, the concentration detected was between 13, 900 to 16, 900 ng/ L diazinon.

Sites in the San Joaquin River Watershed were sampled biweekly during April 1997 to September 1997. In almost all cases, TIEs were conducted only on samples resulting in significant mortality to the test species. Toxicity was detected in eight of twelve samples collected from Orestimba Creek. Significant mortality was observed in three out of eight samples. In all cases, chlorpyrifos was detected at concentrations greater than laboratory’s 96-hour LC50 of 52 ng/L. In one of these samples, diazinon was also detected at concentrations exceeding the laboratory’s 96-hour LC50 of 460 ng/L (Reyes *et al*., 2000). Chlorpyrifos toxicity was also detected on occasion in surface water samples from four agriculturally dominated back sloughs in the San Joaquin-Delta (Deanovic *et al*., 1997).

Diazinon and chlorpyrifos also have been detected at in samples collected from waterways receiving primarily urban runoff. In a study by Bailey *et al.* (1996), 230 samples were analyzed for diazinon. Eighty-five percent of the measured values (195 samples) exceeded the CDFG recommended acute hazard criteria. Ninety samples were analyzed for chlorpyrifos, 80% (72 samples) exceeded the recommended CDFG acute hazard criteria. These chemical and bioassay analyses demonstrate that diazinon and chlorpyrifos are present in urban stormwater runoff at concentrations toxic to sensitive invertebrates.

Novartis, the registrant for diazinon, completed a diazinon probabilistic risk assessment for the Central Valley. The chemical and bioassay studies suggest that the greatest impact of toxicity is likely to occur in watercourses adjacent to orchards with lower concentrations predicted in main stem rivers. The report predicts that the San Joaquin River will experience acutely toxic conditions to the 10% of most sensitive species in January and February, the period of most intensive diazinon off site movement. Novartis concluded that the risk of diazinon alone in the SJR Basin is limited to the most sensitive invertebrates, primarily cladocerans (Novartis Crop Protection, 1997).

Dow AgroSciences, the primary registrant for chlorpyrifos, monitored daily diazinon and chlorpyrifos concentrations in Orestimba Creek a major tributary of SJR for one year from May 1996 through April 1997. Diazinon and chlorpyrifos were measured at concentrations acutely toxic to sensitive organisms like *Ceriodaphnia*, for 50 days during the irrigation season, March to September (Poletika and Robb, 1998).

A total of 13 sites in the LSJR were sampled weekly during nonstorm periods and more frequently during two storm periods in 2000. The sites included five major river and eight minor tributary sites. The highest concentrations of diazinon and chlorpyrifos occurred during the storm periods. Four samples from major river sites (Tuolumne River and two SJR sites) had diazinon concentrations greater than CDFG acute criteria for diazinon. One sample from SJR site exceeded CDFG acute criteria for chlorpyrifos. At the eight minor tributary sites, 24 samples exceeded the diazinon acute criteria and four samples exceeded the chlorpyrifos acute criteria. (Kratzer, 2002)

Extent of Impairment

Beneficial uses affected by diazinon and chlorpyrifos contamination in the SJR are Warm (WARM) and Cold (COLD) Freshwater Habitat (CVRWQCB, 1998). Based on the available data, diazinon and chlorpyrifos in the lower SJR and several tributaries were placed on the 1998 California 303(d) list of impaired waterbodies approved by US EPA in May 1999. The SJR is listed as impaired by diazinon and chlorpyrifos for 130 miles of the SJR from Mendota Dam to the Airport Way Bridge near Vernalis. Monitoring data show that the SJR near Vernalis exceeded the CDFG chronic criterion for diazinon in approximately 30% of samples in 1993 (79 out of 262 samples) and 1994 (36 out of 107) and in 10% of samples in 2000 (8 out of 60) and 2001 (6 out of 44) (Table 1.4). Overall, the chronic criterion was exceeded in 19% of samples collected from 1991 to 2001 (184 out of 953 samples) and the acute criterion was exceeded in11% of samples (102 out of 953). The CDFG chronic criterion for chlorpyrifos was exceeded in 15% of samples (29 out of 194 samples) from 1991 to 2001 in the SJR near Vernalis (Table 1.5). The acute criterion was exceeded in 6% of samples (12 out of 194).

The acute diazinon criterion was exceeded in 19 percent of all samples collected (11 out of 58) in the SJR near Stevinson, which is 60 river miles upstream of Vernalis. The chronic criterion was exceeded in 26 percent of samples (15 out of 58). The acute chlorpyrifos criterion was exceeded in only two percent of samples collected (1 out of 49) and the chronic criterion was exceeded in eight percent of samples (4 out of 49).

The chronic diazinon criterion was exceeded in ten percent of all samples collected (4 out of 40 samples) in SJR near Patterson and in five percent of all samples collected in SJR near Crows Landing (1 out of 20). Patterson and Crows Landing are downstream of the Merced River confluence and upstream of the Tuolumne River confluence. The acute chlorpyrifos criterion was exceeded in only two percent of all samples collected (1 out of 39) in SJR near Patterson and five percent of all samples collected (1 out of 20) in SJR near Crows Landing. The chronic chlorpyrifos criterion was exceeded in eight percent of samples collected (3 out of 39) in SJR near Patterson and in five percent of all samples collected (1 out of 20) in SJR near Crows Landing. There is impairment in all reaches of the LSJR because of the widely distributed sources of diazinon and chlorpyrifos in the watershed, as will be shown in the source analysis section. Table 1.4 and 1.5 show the number of days that diazinon and chlorpyrifos criteria were exceeded from 1991 to 2001.

Table 1.4 Days of Exceeded Diazinon Criteria in San Joaquin River

STATION NAME		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Grand Total
San Joaquin River near Paterson	# of Days Acute Exceeded				0						0	40	0
	# of Days Chronic Exceeded				0						0		4
	# of Sampling Days				5						1		40
	Max Concentration(ppb)				0.011						0.022		0.067
San Joaquin River near Crows Landing	# of Days Acute Exceeded											0	0
	# of Days Chronic Exceeded											1	1
	# of Sampling Days											20	20
	Max Concentration(ppb)											0.05	0.05
San Joaquin River near Stevenson	# of Days Acute Exceeded	0	1	1	0						2	7	11
	# of Days Chronic Exceeded	1	2	1	0						3	8	15
	# of Sampling Days	3	5	2	1						13	34	58
	Max Concentration (ppb)	0.05	0	0.26	0						0.15	0.289	0.289
San Joaquin River near Vernalis	# of Days Acute Exceeded	2	14	55	17	0		0	4	2	2	6	102
	# of Days Chronic Exceeded	8	33	79	36	1		3	7	3	8	6	184
	# of Sampling Days	156	197	262	107	9		34	42	42	60	44	953
	Max Concentration (ppb)	0.1	0.53	1.4	0.71	0.08		0.07	0.1	0.15	0.1	0.235	1.4

Acute: short term exposure (24-96 hours) Chronic: long term exposure (4 days)
Acute Criteria: 80 ng/ L Chronic Criteria: 50 ng/ L

Table 1.5 Days of Exceeded Chlorpyrifos Criteria in San Joaquin River

STATION NAME		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Grand Total
San Joaquin River near Patterson	# of Days Acute Exceeded				1							0	1
	# of Days Chronic Exceeded				3							0	3
	# of Sampling Days				5							34	39
	Max Concentration(ppb)				0.073							0.11	0.183
San Joaquin River near Crows Landing	# of Days Acute Exceeded											1	1
	# of Days Chronic Exceeded											1	1
	# of Sampling Days											20	20
	Max Concentration(ppb)											0.093	0.093
San Joaquin River near Stevenson	# of Days Acute Exceeded	0			0						1	0	1
	# of Days Chronic Exceeded	0			0						3	1	4
	# of Sampling Days	1			1						13	34	49
	Max Concentration(ppb)	0			0						0.156	0.065	0.221
San Joaquin River near Vernalis	# of Days Acute Exceeded	0	1	8	2	1		0	0	0	0	0	12
	# of Days Chronic Exceeded	0	5	14	7	2		0	0	0	1	0	29
	# of Sampling Days	2	30	38	18	9		7	9	11	26	44	194
	Max Concentration(ppb)	0.01	0.258	0.536	0.17	0.07		0.03	0	0	0.136	0.167	1.36757

Acute: short term exposure (24-96 hours) Chronic: long term exposure (4 days)
Acute: 25 ng/ L Chronic: 14 ng/ L

2.0 NUMERIC TARGET

Section 303(d)(1)(C) of the Clean Water Act states that TMDLs "shall be established at a level necessary to implement the applicable water quality control standards…." Once established, the numeric targets identify the specific in-stream goals or endpoints for the TMDL, which equate to the attainment of the water quality standards established in the Basin Plan. Numeric targets for the SJR diazinon and chlorpyrifos TMDL must equate to diazinon and chlorpyrifos loads and concentrations in the SJR that meet the appropriate existing water quality objectives for the SJR and are protective of designated beneficial uses. The numeric targets for this TMDL will be proposed to be established as water quality objectives for the SJR as part of the Basin Plan Amendment for this TMDL.

2.1 Proposed Numeric Target

The Diazinon and Chlorpyrifos Numeric Target Analysis report for this TMDL (Azimi *et al.* 2001 included in Appendix 2) summarizes the available data and existing criteria upon which to base numeric targets for chlorpyrifos and diazinon in the SJR. The following alternative methods for developing a chlorpyrifos and diazinon numeric target were evaluated: based on the State's anti-degradation policy, US EPA water quality criteria development methodology, US EPA water quality criteria methodology as used by CDFG, Probabilistic Ecological Risk Assessment as used by Novartis Crop Protection, microcosm/mesocosm studies, and literature findings. Regional Board staff has determined, based on currently available information, that an acceptable target would be between "zero" and the target derived by CDFG using US EPA water quality criteria development methodology: diazinon (50 ng/L 4-day average and 80 ng/L 1-hour average), chlorpyrifos (14 ng/ L 4-day average and 25 ng/ L 1-hour average).

Establishment of final numeric targets and water quality objectives, however, will also depend on the evaluation of a number of factors. These factors include: the environmental characteristics of the watershed; water quality conditions that could be reasonably achieved through the coordinated control of all factors which affect water quality in the area; economic considerations; the need for developing housing in the region; and the need to develop and use recycled water (§13241; Porter-Cologne Water Quality Act). For the purpose of describing the TMDL, it is assumed that the numeric targets will be the CDFG criteria. The TMDL will be modified based on the water quality objectives adopted by the Regional Board.

3.0 SOURCE ANALYSIS

The source analysis describes sources of chlorpyrifos and diazinon to the LSJR, and the magnitude, timing, and seasonality, of chlorpyrifos and diazinon loads. Chlorpyrifos and diazinon concentration and associated flow data collected by multiple agencies were compiled and evaluated to assess mass loading in surface waters. This mass loading was used to estimate the spatial and temporal variability in pesticide load. Chlorpyrifos and diazinon application data was compiled and evaluated to assess sources. The complete source analysis report will be available as a separate document (Leva *et al*., 2002).

3.1 Data Used for Source Analysis

Regional Board staff reviewed available reports and data for the SJR Basin. Data used in this source analysis includes pesticide use reports, pesticide water column data, and flow data.

Chlorpyrifos and Diazinon Water Column Concentration Data

The two main sources used were data from the California Department of Pesticide Regulation (CDPR) Surface Water Database and the US Geological Survey (USGS) Database. A complete dataset collected for this analysis was compiled and entered into databases. An excerpt from that dataset is presented in Appendix A for chlorpyrifos and Appendix B for diazinon in the source analysis document (Leva *et al*., 2002). These two databases contain the analytical information used in this source anaysis. Each record shows a unit of concentration and a level of detection. The dataset will be posted on the Regional Board website and can be provided upon request. Review of a partial data set collected prior to 1990 indicates that the critical analytical elements such as quantitation limits and quality control sample results are not available for most of this earlier data. Since the quality of this data could not be verified, most data collected prior to 1990 was not used in this source analysis.

Chlorpyrifos and Diazinon Use Data

Pesticide use data was obtained from the California Department of Pesticide Regulation's (CDPR) Pesticide Use Report (PUR) database. In January 1990, a new California law came into effect that required growers to report all pesticides used on all crops. Monthly use reports, submitted to the county agricultural commissioner, are submitted to and compiled by the CDPR. In addition, all pesticide application on golf courses, parks, roadside and railroad rights of way, cemeteries, rangeland and pasture are also subject to reporting requirements. Use is also reported for professional applications such as structural fumigation and greenhouses. Currently, non-professionally applied home uses are exempt from the reporting requirement. Reported agricultural and urban use data from 1995 through 2000 were examined for this source analysis. Data from earlier years were not included because limited quality control checks were conducted on this earlier data.

Flow Data

Eight flow stations have been identified that measure discharge from the major tributaries to the SJR, and along the mainstem of the river. Six are maintained by the USGS, and two are maintained jointly by USGS and Department of Water Resources (DWR). Normally it takes about one year after the time of measurement for the data to be reviewed for accuracy and published; provisional flow data is available, but is subject to change. The SJR near Vernalis, for example, has published records for 1990 through September 1999. Provisional data was used for the period October 1999 through April 2001.

3.2 Sources and Mechanisms of Transport

Monitoring by various agencies and other groups has confirmed the widespread occurrence of diazinon, chlorpyrifos, and other pesticides in the SJR and tributaries. The main sources of these compounds can be generalized into agricultural and urban sources. Agricultural sources can further be subdivided according to seasonality. Dormant season pesticide application occurs in the LSJR during the winter months, generally between December and March. In-season application to crops in the LSJR basin occurs generally between approximately March/April through September.

During the dormant season, the primary mechanism by which the pesticides enter surface water is through runoff resulting from winter rains. Pesticide residue deposited on the trees and the ground that does not volatilize or infiltrate into the soil migrates with runoff waters during rain events. During the irrigation season, residual chlorpyrifos and diazinon migrates with the irrigation water from agricultural fields and enters tributaries that flow into the LSJR. Other potential mechanisms by which these diazinon and chlorpyrifos are introduced into surface water are via localized drift and atmospheric deposition. Volatilized pesticide particles can collect in condensed rain droplets that make their way back to surface waters.

Diazinon and chlorpyrifos from urban sources are introduced into surface water through urban storm runoff as well as atmospheric deposition. Urban sources include both reported and unreported use of these compounds. Various chemical use patterns in urban areas, including structural and landscape applications, restaurant and building pest-control, use of animal-care products, and home fruit and vegetable garden can potentially contribute to the presence of these pesticides in surface water.

Seasonality Component of Agricultural Sources

Dormant Season

Pesticides applied during the dormant season are periodically washed off fields by storms large enough to generate runoff. For the project area, studies have shown that the amount of pesticide washed off is usually a very small fraction of the amount applied, ranging between 0.05 and 0.13 percent for diazinon and 0.06 to 0.08 percent for chlorpyrifos (Kratzer *et al.*, 2001 draft; Kratzer, 1999). However, it is significantly large enough to increase the stream concentrations above the suggested numeric targets and to cause toxicity. The amount of pesticide available for runoff will be approximately equal to the amount applied during the dry period preceding the rainfall event, minus any that has degraded, infiltrated into the ground, or remained bound to sediment particles at the ground surface. Highest concentrations are most likely to occur with the first major storm after a prolonged dry period.

In addition to application amount, other factors that may affect the amount of storm runoff and pesticide loading. Soils with poor drainage characteristics, such as on the west side of the SJR where the soil is fine-grained and highly erodible, may have higher runoff potential than the more permeable soils on the east side. This was the reason suspected for higher detection rates of carbofuran, endosulfan, and oxamyl from the west side than on the east side, despite similar reported use in both areas (Ross *et al.*, 1999). Antecedent moisture conditions may also be important. Pesticides applied to fields with higher moisture content may be expected to generate larger storm loads than if the soil was more dry. In the latter, a greater amount of precipitation and consequently pesticide will be lost through infiltration into the soil. Other factors affecting runoff include field slope and the type of cover crop.

Irrigation or In-Season

In contrast to the dormant season, in-season or irrigation season loading in the SJR is more continuous, though generally smaller. At times, however, concentrations above the chronic or acute toxicity criteria occur level. The irrigation season is defined as April through September, although storms occasionally occur during the earlier and later parts of this period.

There are two major pathways by which pesticides migrate to a stream during the irrigation season: mobilization of pesticides from plant and soil surfaces by irrigation water and: direct drift from aerial application. Applied pesticides settle onto both plant foliage and soil. Subsequent irrigation washes the pesticide off the foliage and soils into the river. Direct drift from aerial application has been documented for rice crops in Colusa and Glenn counties, where aerial application of methyl parathion has been found to be a significant pathway (Kollman *et al.*, 1992).

The method of irrigation may affect the magnitude of pesticide loading in the river. With furrow irrigation, for example, surface water returns from the end of the field, referred to as tailwater, may discharge to a drainage channel that leads to a stream. In some cases, however, systems are in place so that tailwater is recycled to another field or blended with fresh irrigation water and reapplied to another field. Tailwater return flows from furrow irrigation probably generate the largest loads because large volumes of surface water runoff are discharged directly. Sprinkler irrigation, though likely to increase pesticide wash-off from foliage, may generate less tailwater if used appropriately. Drip irrigation systems typically generate little or no runoff. If appropriately used, such irrigation methods are not likely to be large sources of irrigation season loading.

Other Considerations

Several factors, including pesticide application, hydrology, and chemical and physical properties influence the occurrence and distribution of chlorpyrifos and diazinon in SJR surface waters. As noted above, introduction of chlorpyrifos and diazinon into surface water is believed to primarily occur through runoff. In general, pesticide residue on crops or on the soil that has not volatilized or infiltrated into the ground migrates with surface runoff either in runoff associated with rain events or with irrigation return flow. Other means are through localized drift, atmospheric deposition and spills resulting from improper mixing and loading practices.

Atmospheric deposition of pesticides is most likely to affect stream water quality during runoff events when precipitation and direct surface runoff are the major sources of streamflow (USGS, 1995). Locally high concentration of pesticides in rain and air are very seasonal, correlated to local use, and usually occur during the spring and summer months. High concentrations of OP pesticides also can occur in rain, air, and fog during the fall and winter months in areas where there is high use as in the stone-fruit orchards in the Central Valley. Studies are currently being conducted to quantify the atmospheric deposition of chlorpyrifos, diazinon, and other pesticides in the SJR Basin.

Inappropriate mixing and loading practices and poor disposal procedures result in spills of concentrated liquid or dry material on the soil surface which can contribute to the presence of these pesticides in surface water. Studies may be needed to quantify the amount of pesticides in surface water attributable to inappropriate mixing, loading and disposal practices.

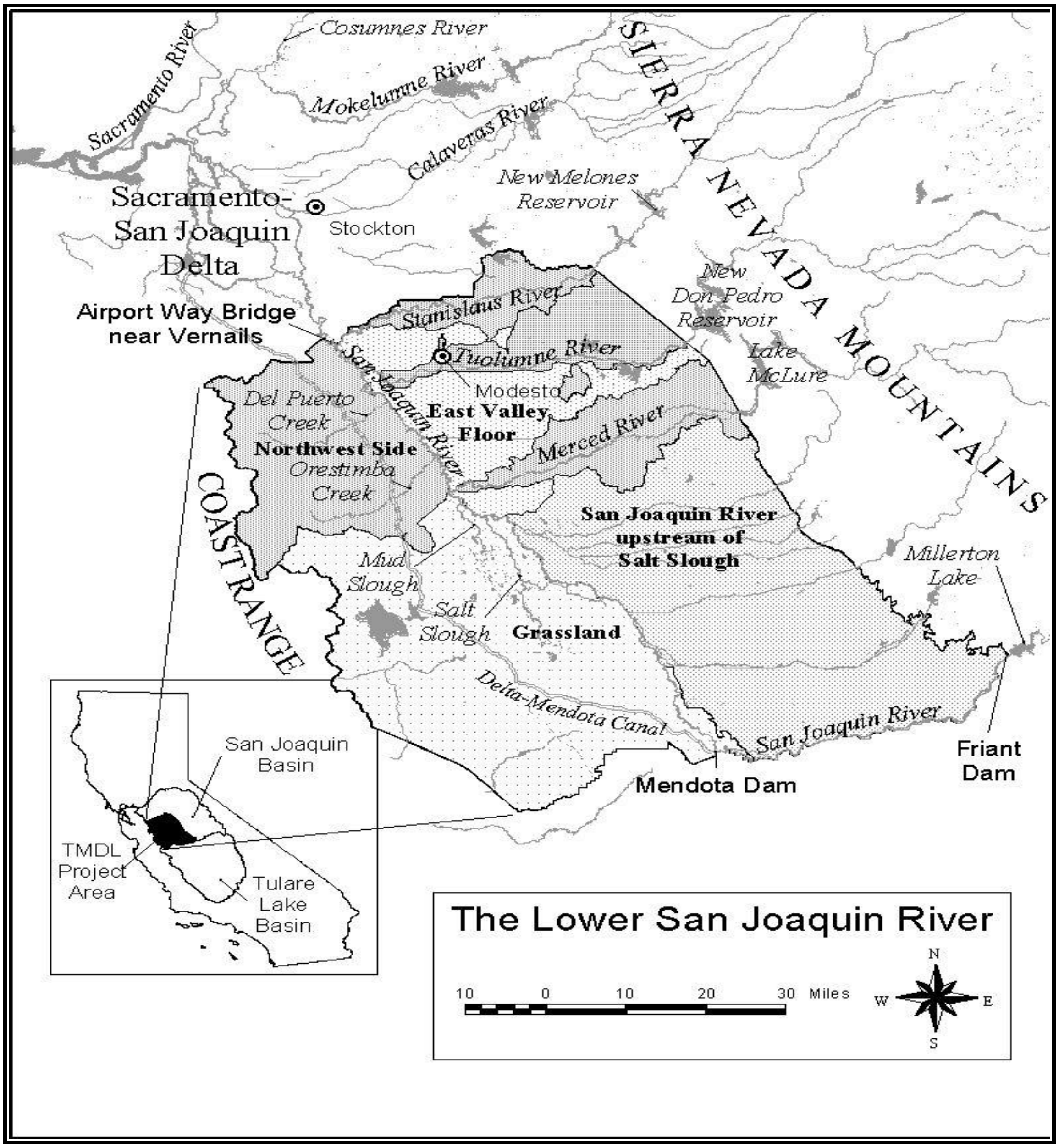
Chemical properties that are important in the transport of OP pesticides are those which affect its persistence in the environment and those which characterize its movement from one environmental matrix to another, such as movement from soil to water or movement from water to air (Larson *et al.*, 1997). Properties that affect a pesticide's ability to move from one environmental matrix to another are water solubility, sorption coefficient, and Henry's law constant. The known chemical characteristics of diazinon and chlorpyrifos indicate that they will tend to move into the liquid water phase and in the sediments in a wet environment and will tend to remain in that phase. Water therefore provides an efficient transport mechanism for the offsite movement of these pesticides. Because the frequency of storms during the dormant spray season generally falls within the range of the pesticides' persistence in the environment, it is reasonable to conclude that winter storm water runoff facilitates the movement of diazinon from its point of application to streams in the SJR Basin.

3.3 Description of Drainage Basins Used

Pesticide sources were assessed using sub-areas within the basin to facilitate the discussion of potential sources for the project area and to provide the framework for a compliance monitoring program. Due to limited data, however, not all sub-areas will have representative loading information. A brief description of the sub-areas presented in Figure 3.1 that were used for this source analysis follows. A more comprehensive description by Oppenheimer *et al*. (2002) is attached in Appendix E of the source report (Leva *et al*. 2002).

The seven sub-area delineations are based on both the geographic distribution of available monitoring data and common physiological characteristics. Because the San Joaquin Valley floor is relatively flat and water supply management has significantly altered natural drainage patterns, the LSJR river watershed cannot be broken down into its component sub-watersheds solely by using surface elevation data. A GIS was used to delineate and assess the characteristics of each sub-area. The geographic analysis relied on existing spatial data developed by outside agencies, including the DWR, USGS, U.S. EPA, and the U.S. Bureau of Reclamation (USBR). Information describing the sources of the spatial data and GIS processing information (metadata) is given in Appendix B of the Salt/Boron TMDL or in Appendix E of the source report.

Figure 3.1 Sub-Areas of the Lower San Joaquin River



Subarea Descriptions

Lower San Joaquin River upstream of Salt Slough

The LSJR upstream of Salt Slough drains 1,476 square miles on the east side of the LSJR upstream of the Salt Slough confluence. It includes the portions of the Bear Creek, Chowchilla River and Fresno River watersheds that are contained within Merced and Madera Counties. The northern boundary of the sub-area generally coincides with the Merced River drainage area. The western and southern boundaries follow the San Joaquin River from the Salt Slough confluence to Friant, except for the lands within the Columbia Canal Company which are excluded. Columbia Canal Company lands are included in the Grassland Sub-area. The LSJR upstream of Salt Slough site is represented by a sampling point at the LSJR at Lander Ave.

Effective Drainage Area of LSJR Upstream of Salt Slough

Drainage from the area encompassed by the LSJR upstream of Salt Slough sub-area flows to the LSJR at Lander Ave only during high flow periods. During the irrigation season, the effective drainage area is a 523-square-mile subset of lands within the LSJR upstream of the Salt Slough Sub-area. This area is predominantly comprised of the portion of the Bear Creek watershed that is contained entirely within Merced County. Also during the irrigation season, flows in the SJR downstream of Mendota Dam are entirely diverted from the SJR at Sack Dam. The effective drainage area upstream of the Salt Slough is therefore split into two separate drainages.

Merced River

The Merced River sub-area is represented by a sampling point at the Merced River at River Road. The area is comprised of the Merced River watershed downstream of the Merced-Mariposa county line. Included here is the area above the Sand and Mustang Creek watershed from which irrigation water is diverted to Highline Canal. The Merced River sub-area is 294 square miles in size.

Tuolumne River

The Tuolumne River sub-area is represented by a sampling point at the Tuolumne River at Shiloh Bridge. The area is comprised of the Tuolumne watershed downstream of the Stanislaus-Tuolumne county line. The sub-area is 253 square miles in size.

Stanislaus River

The Stanislaus River sub-area is represented by a sampling point at the Stanislaus River at Caswell State Park. This area is comprised of the Stanislaus River watershed downstream of the Stanislaus-Calaveras county line. The sub-area is 152 square miles in size.

East Valley Floor

The East Valley Floor sub-area includes 476 square miles of land on the east side of the LSJR that drains directly to the LSJR between Vernalis and the Salt Slough confluence. The sub-area is largely comprised of the land in between the major east-side drainages of the Tuolumne, Stanislaus, and Merced Rivers. This sub-area lies within eastern

Stanislaus County and northeastern Merced County. Numerous drainage canals, including the Harding Drain, and natural drainages drain this sub-area.

Northwest side

The Northwest sub-area is 603 square miles in size. The Northwest Side sub-area generally includes the lands on the West side of the LSJR from Vernalis to the LSJR's confluence with the Merced River. In Oppenheimer *et al.* (2002), this sub-area includes the entire drainage area of Orestimba, Del Puerto, and Hospital/Ingram Creeks. In this analysis, Orestimba will be evaluated separately. The eastern boundary of the sub-area follows the LSJR from Vernalis to the Merced River confluence and the western boundary follows the crest of the Coast Range. The sub-area is primarily located in Western Stanislaus County except for a small area that extends into Merced County in the vicinity of Gustine and the CCID Main Canal.

Orestimba Creek

Because of the extensive monitoring data available, it is possible to examine this watershed closely, and in the analysis of use and loads, Orestimba Creek is often looked at separately. This area is comprised of the Orestimba Creek watershed and is 204 square miles in size during the storm season and 11 square miles in size during the irrigation season. It is represented by a sampling point at Orestimba Creek at River Road. In the analysis of Pesticide Use Report data, the points analyzed were adjusted according to the season.

Grassland Watershed

The Grassland sub-area encompasses 1,360 square miles on the west side of the LSJR in portions of Merced, Stanislaus, and Fresno Counties. This sub-area is includes the Mud Slough, Salt Slough, and Los Banos Creek watersheds. The western boundary of this sub-area is generally formed by the LSJR from upstream of the Merced River confluence to downstream of the Mendota Pool. The Grassland sub-area extends across the LSJR, to the east side of the San Joaquin Valley, to include the lands within the Columbia Canal Company's jurisdiction. The Columbia Canal Company was included in the Grassland sub-area because it receives supply water from the Mendota Pool and its drainage is eventually discharged into the Grassland sub-area in supply water diverted at Sack Dam. The eastern boundary of the sub-area generally follows the crest of the Coast Range except for the lands within San Benito County on the east-side of the Coast Range, which has been excluded.

Total

The area referred to as "total" in the pesticide load section refers to the entire project area and is represented by samples collected at SJR near Vernalis.

3.4 Pesticide Use

Use Reporting

Application data for chlorpyrifos and diazinon were examined using the CDPR pesticide use reports (PUR) for 1995 through 2000. These reports are compiled in the CDPR PUR database.   Total use and seasonal use trends were examined for the entire TMDL project area (Figure 3.1). The percent of under or over reporting is not known; however, for agricultural uses, Merced and Stanislaus Agricultural Commissioners estimate that unreported diazinon and chlorpyrifos applications account for up to 10% of all applications (K.Wright, D. Cismowski, personal communication). The percent of underreporting for reportable non-agricultural uses is not known. Additionally, there are no reporting requirements for non-professionally applied pesticide use and no non-professionally applied pesticide use data is unavailable.

Changes in Use Status

The USEPA announced revised risk assessments for chlorpyrifos and diazinon in 2000. For diazinon, the risk mitigation actions include the cancellation of products for indoor residential and non-residential uses, with all sales of products for indoor use ending December 2002 (USEPA, 2000a). Outdoor non-agricultural uses of diazinon will also be phased out. Provisions of the agreement between USEPA and registrants involving chlorpyrifos are described in the revised risk assessment for this chemical (USEPA, 2000b). Sales of chlorpyrifos products for most indoor and outdoor residential uses must cease at the end of December 2002. For agricultural uses, about 30% of the agricultural crops on which diazinon is currently approved for application are proposed to be cancelled; use will be retained on over forty other agricultural crops. There are reduced and/or cancelled uses of chlorpyrifos on apples, tomatoes, and grapes. The timeline of changed or eliminated uses for agricultural commodities or non-agricultural uses are shown in Table 3.1. These changes in use should result in a marked decrease in use of these products for urban purposes.

General Use Patterns

Application data for the entire TMDL project area will be used in this discussion of the general use trends. Effective drainages and differences in areas drained for certain sub-areas depending on season (for example, the drainage areas for Orestimba Creek varies depending on dormant versus in-season time periods) will be considered in the discussion involving seasonality. The approach used in this analysis was to first determine the commodities that account for highest use and to determine the seasonality of use for these particular commodities.

Figures 3.2 and 3.3 show the annual diazinon and chlorpyrifos use trends for the area of interest for urban and agricultural uses listed in the PUR. In general, the amount of diazinon and chlorpyrifos reported used for agricultural purposes shows a decreasing trend over the time period examined. Reported urban use of diazinon remains more constant with the exception of the 2000 data which shows a spike in use relative to previous years. As will be shown in the following sections, most of this increase in use is attributable to an increase in use in structural pest control. Reported urban use of chlorpyrifos has remained stable during the last four years.

Table 3.1 Summary of Chlorpyrifos and Diazinon Use Status Based on Revised Risk Assessments.

COMPOUND NAME	USE CATEGORY		Effective Date
Diazinon	Home and Non-Agricultural Uses	All indoor uses	**February 2001**: cancellations effective after 30 day public comment period **1 March 2001**: manufacturing use products can no longer be used to formulate end use products for indoor uses 31 December 2002 : end of retail sale
		Outdoor non-agricultural uses (outdoor residential including lawn and garden; outdoor non-agricultural uses)	**2003**: 50% or more reduction in amount of diazinon produced by technical registrants **30 June 2003**: end of product formulation **31 August 2003**: end of sale to retailers **31 December 2004**: start of buy -back by technical registrant of existing products from retailers; cancellation or expiration of product registrations
	Agricultural Uses	Crops: Alfalfa, bananas, beans (dried), Bermuda grass, celery, red chicory (radicchio), citrus, clover, coffee, cotton, cowpeas, cucumbers, dandelions, kiwi, lespedeza, parsley, parsnips, pastures, peppers, irish potatoes, sweet potatoes, rangeland, sheep, sorghum, spinach, squash (summer and winter), strawberries, swiss chard, tobacco, tomatoes, turnips	**February 2001**: cancellations effective after 30-day comment period
Chlorpyrifos	Home and Non-Agricultural Uses	Home lawn and most outdoor uses; Crack and crevice, and most indoor uses; termiticides (full barrier post-construction use) Indoor areas where children could be exposed (e.g. schools) Outdoor areas where children could be exposed (e.g. parks)	**1 December 2000**: stop formulation **1 February 2001**: formulators stop sale **31 December 2001**: retailers stop sale
		Termiticides: Spot and local post-construction use	**1 December 2000**: formulation stopped unless label has stop use date of 31 December 2002
		Termiticides: pre-construction use	**31 December 2004**: stop production
		Residential use of containerized baits (in child resistant packaging)	Use allowed to continue
		Indoor areas where children will not be exposed	Use allowed to continue but new end-use product labels need to reflect only these uses as of 1 December 2000
		Outdoor areas where children will not be exposed	Use allowed to continue but new end-use product labels need to reflect only these uses as of 1 December 2000
		Public Health Uses: fire ant mounds, mosquito control	For professional use only Use allowed to continue but new end-use product labels need to reflect only these uses as of 1 December 2000
	Agricultural (Food) Uses	Apples	**August-September 2000**: production of chlopyrifos labeled for post-bloom application prohibited; pre-bloom dormant application is allowed **31 December 2000**: post-bloom application prohibited Tolerance lowered
		Tomatoes	**August-September 2000**: production of products for tomato use prohibited **31 December 2000**: Use cancelled Tolerances revoked
		Grapes	Tolerance will be lowered
		All agricultural uses	**1 December 2000**: new end-use products will be classified for restricted use or packaged in large containers; new products must bear revised Restricted Entry Intervals (REIs)

Figure 3.2 Summary of Amount of Diazinon Applied in the SJR Basin (1995 to 2000)

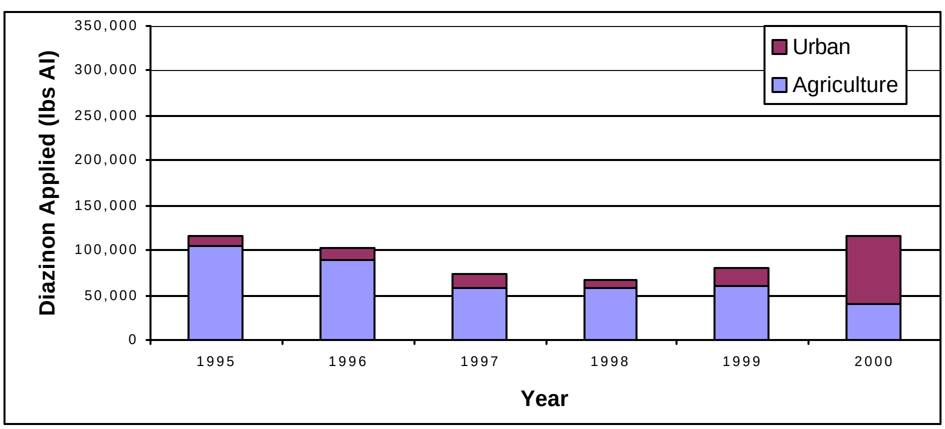
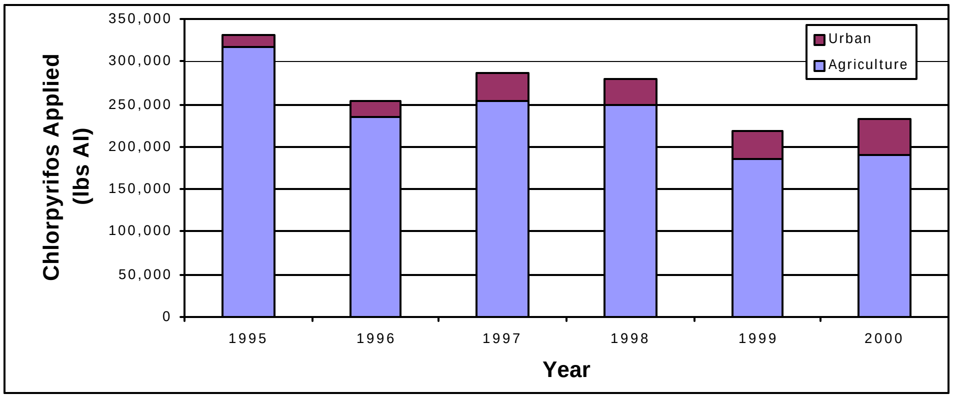


Figure 3.3 Summary of Amount of Chlorpyrifos Applied in the SJR Basin (1995 to 2000).



The specific types of uses showing high average annual applications (in pounds active ingredient or lbs AI) for urban and agricultural purposes for diazinon and chlorpyrifos are shown in Tables 3.2 and 3.3. Agricultural use accounts for about 60% and 80% of the reported use for diazinon and chlorpyrifos, respectively. For both compounds, the primary non-agricultural reported use is for structural pest control. Agricultural use of diazinon is primarily for nut and stonefruit orchards.

With the exception of alfalfa, none of the crops listed for cancellation represent any of the top crops showing the highest average annual diazinon use in the TMDL project area. In the case of alfalfa, which is one of the crop uses listed for cancellation, the use of diazinon on this crop in the project area has been reported as reducing drastically beginning in 1997. No use was reported from 1999 through 2000. Prior to 1997, diazinon use on alfalfa accounted for only approximately 2% of the total reported agricultural use. For non-agricultural uses, the use report data for structural use does not distinguish between indoor and outdoor use, therefore, it is not known how much of the structural use component will be reduced by the cancellation of any indoor uses. Outdoor uses will continue until 2003, and product cancellation for this type of use does not occur until 2004. These approved outdoor uses includes non professionally applied residential outdoor use. The contribution of this type of use in terms of amount applied is not known since this is not reported in the PUR.

Table 3.2 Reported Uses of Diazinon in SJR Basin (1995 to 2000).

CROP	Diazinon Annual Season Use (pounds of active ingredient)									Average Acreage Planted	Average Acreage Treated	Average Rate of Application (lbs/acre)
	1995	1996	1997	1998	1999	2000	Total	Average per year	% Average Annual Use			
Structural Pest Control	*23,731*	*27,156*	*37,884*	*31,691*	*39,750*	*101,351*	*261,563*	*43,594*	*38*			
Almond	59,491	48,584	28,112	31,504	34,846	11,761	214,298	35,716	*32*	31,251	21,418	1.67
Peach	9,225	10,838	6,693	6,589	5,491	6,365	45,201	7,534	*7*	14,192	8,830	0.85
Apricot	6,565	5,553	1,997	4,378	3,430	2,978	24,901	4,150	*4*	6,016	3,216	1.29
Prune	3,652	2,475	1,727	4,642	3,764	3,563	19,823	3,304	*3*	2,253	1,957	1.69
Cantaloupe	2,816	2,963	4,268	866	2,951	2,149	16,013	2,669	*2*	5,557	5,028	0.53
Apple	4,714	4,349	2,914	1,251	1,468	1,271	15,967	2,661	*2*	2,034	1,533	1.74
Nectarine	2,538	2,319	1,690	1,510	1,806	2,415	12,278	2,046	*2*	7,758	2,991	0.68
Melons	1,860	1,621	1,840	1,499	1,747	999	9,566	1,594	*1*	3,498	3,258	0.49
Walnut (English, Persian)	2,130	1,620	2,650	999	317	1,353	9,069	1,512	*1*	3,637	939	1.61
Plum (including wild plums for human consumption)	2,617	1,861	1,244	935	776	1,046	8,479	1,413	*1*	763	665	2.13
Tomatoes (for processing/canning)	1,036	1,554	285	808	797	3,554	8,034	1,339	*1*	1,478	1,361	0.98
Landscape Maintenance	*780*	*973*	*1,310*	*1,365*	*1,664*	*1,521*	*7,613*	*1,269*	*1*			
Alfalfa	2,912	3,178	186	302	0	0	6,578	1,096	*1*	2,831	2,640	0.42
Cherry	714	834	731	621	165	103	3,168	528	*0*	360	334	1.58
Watermelons	153	210	789	300	367	127	1,946	324	*0*	670	413	0.79
Grapes (wine)	618	298	324	322	257	68	1,887	315	*0*	436	337	0.93
Other (Agricultural)	3,212	1,537	1,770	2,317	1,040	2,794	12,670	2,112	*2*	22,222	3,498	0.60
Other (Urban)	*134*	*21*	*102*	*18*	*254*	*145*	*674*	*112*	*0*			

Table 3.3 Reported Uses of Chlorpyrifos in SJR Basin (1995 to 2000)

CROP	Chlorpyrifos Annual Use (pounds of active ingredient)									Average Acreage Planted	Average Acreage Treated	Average Rate of Application (lbs/acre)
	1995	1996	1997	1998	1999	2000	Total	Average per year	% Average Annual Use			
Almond	74,145	101,005	106,087	111,320	78,234	88,633	559,424	93,237	31	105,240	58,641	1.59
Structural Pest Control	*67,207*	*64,639*	*60,401*	*62,579*	*59,817*	*56,114*	*370,757*	*61,793*	*21*			
Cotton	112,365	22,962	42,630	21,552	16,962	16,643	233,114	38,852	13	56,639	41,912	0.93
Alfalfa	57,770	43,971	34,890	38,461	20,971	26,653	222,716	37,119	12	79,679	62,901	0.59
Walnut (English, Persian)	33,109	33,165	29,037	27,850	24,547	23,520	171,228	28,538	10	51,266	32,463	0.88
Apple	14,624	11,907	12,298	14,573	6,574	3,934	63,910	10,652	4	16,208	6,879	1.55
Corn (forage/fodder)	12,382	7,129	11,055	7,593	10,919	11,563	60,641	10,107	3	14,873	9,253	1.09
Sugarbeet	3,376	3,343	4,614	6,105	6,331	3,052	26,821	4,470	1	6,153	5,183	0.86
Orange	3,929	2,699	1,774	4,971	5,771	2,014	21,158	3,526	1	1,731	1,006	3.50
Sweet Potato	1,040	1,699	3,155	2,983	5,366	3,924	18,167	3,028	1	1,805	1,530	1.98
Grapes (table)	0	508	1,805	5,659	3,415	2,300	13,687	2,281	1	1,796	1,145	1.99
Asparagus	194	2,699	1,800	112	1,739	2,457	9,001	1,500	1	1,744	1,561	0.96
Peach	1,161	1,505	473	1,215	982	849	6,185	1,031	0	1,272	573	1.80
Citrus Fruits (unspecified)	714	706	713	1,030	427	984	4,574	762	0	620	284	2.68
Grapes (wine)	4	183	39	1,172	531	784	2,713	452	0	324	231	1.96
Broccoli	884	0	232	0	1,397	161	2,674	446	0	624	418	1.07
Landscape Maintenance	*565*	*614*	*574*	*136*	*368*	*302*	*2,559*	*427*	*0*			
Other (Agricultural)	1,443	1,527	2,629	3,582	2,327	1,879	13,387	2,231	1	8,928	5,136	0.43
Other (Urban)	*142*	*589*	*195*	*917*	*287*	*10,598*	*12,728*	*2,121*	*1*			

Urban Pesticide Use

Considerations in Evaluating Urban Use

As shown in Figure 3.2 and Figure 3.3, with the exception of diazinon in the year 2000, the majority of diazinon and chlorpyrifos reported used annually is for agricultural purposes. There are two difficulties using the CDPR PUR database to evaluate use in the urban environment. First, the actual pesticide use for records in the database without any associated CMTRS[3] must be determined. While all urban uses are reported without associated CMTRS, it may not be true that all of these data were non-agricultural. It was however assumed that all such records could be assigned to urban use. Validity of this assumption was checked in two ways. First, the University of California Integrated Pest Management (UCIPM) database[4] for the counties of Merced and Stanislaus were examined for the years 1995 through 1996. This database uses CDPR PUR data and categorizes them into various uses. The urban use data from the UCIPM database and for the non-CMTRS data from the CDPR data was nearly identical for these two counties. Secondly, all categories that came up with no associated CMTRS data were examined to determine whether any categories were agricultural uses. The percentage of agricultural uses that had no associated CMTRS was less than one percent.

The second problem associated with using this database for urban uses is that because the data had no associated CMTRS, it was not possible to determine whether the reported use fell within the project area. It was only known in what county the use was reported. To adjust for this, a GIS was used to determine what percentage of the urban areas in each county actually fell within the project area. For each category, the total use was multiplied by the percent of urban area that falls within that section of the project area.

General Trends in Reported Urban Use

Some of the uses of diazinon and chlorpyrifos in the urban setting include reported uses such as structural pest control, professional landscape use, and unreported uses such as homeowner applied landscaping uses. Based on the PUR data, the primary reported non-agricultural use for both diazinon and chlorpyrifos is structural pest control as shown in Table 3.4. With the exception of the use in 2000, diazinon use for structural pest control ranged from 23,000 to 39,000 lbs active ingredient (AI)(Table 3.2). There is an unexplained spike to 101, 351 lbs AI in 2000. Chlorpyrifos use for structural pest control ranged from 56,000 to 67,000 lbs AI (Table 3.4) On the average, for the period examined, use for structural pest control accounted for 96% to 97% of the reported urban uses of chlorpyrifos and diazinon while landscape maintenance and other uses only accounted for 1% to 3% of the reported urban uses (Table 3.4).

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[3] CMTRS is a designation of a single specific one square-mile section of land. It is a reference to the Township and Range system and is referred to using a combination of the first letters of each of the words that designate a component:
C: County M: Meridian T: Township R: Range S: Section
A more comprehensive definition can be found in Appendix F of the SJR Diazinon and Chlorpyrifos TMDL Source Analysis Report.

[4] The University of California Integrated Pest Management (UCIPM) Program maintains a database of pesticide use in California by county (http://www.ucipm.ucdavis.edu). The data is obtained from the California Department of Pesticide Regulation and undergoes additional quality assurance measures prior to being included in the database.

Table 3.4 Amount of Diazinon and Chlorpyrifos Used for Non-Agricultural Purposes (1995-2000)

	Use Category (lbs active ingredient)		
Compound	Structural Pest Control	Landscape Maintenance	Other (Urban)
Chlorpyrifos	61793	427	2121
Diazinon	43594	1269	112
Percent of Use (chlorpyrifos)	96%	1%	3%
Percent of Use (diazinon)	97%	3%	0%

Due to a lack of associated CMTRS, reported urban use data could not be associated with specific sub-areas. Instead, they were evaluated according to use per county. The counties of Stanislaus and Merced account for 74% of the urban makeup of the project area while the remaining counties of Madera, Fresno and San Joaquin, account for the remaining 26%. The trends are similar for both compounds. Stanislaus County contributes an average of 63% of the reported diazinon urban use and 65% of the reported chlorpyrifos urban use in the project area. The disproportionately high use reported for this county may be due to the fact that this county includes the largest urban center in the area. Merced County contributes 25% of the reported diazinon urban use and 29% of the reported chlorpyrifos urban use in the project area. These two counties, which account for 74% of the urban areas, account for 90% of the urban use of diazinon and chlorpyrifos, while the remaining three counties, which make up 26% of the urban areas accounts for 8% to 10% of the reported urban use of diazinon and chlorpyrifos.

Type of Urban Use and Potential for Runoff

Diazinon and chlorpyrifos used in the urban setting can reach surface waterways via the following pathways: direct release to surface water, storm drain release, sewer release, outdoor impervious surface release, plant or soil release, indoor release, underground release (Moran, 2001). It is unclear whether reported indoor applications of chlorpyrifos or diazinon are included in the "structural pest control" category. It is also unclear how much, if any, of what is applied indoors has the potential to reach surface waters. For example, prior to restriction in use, one of the allowed indoor uses for diazinon was application to carpets. When carpets are washed, washwater has the potential to reach surface water when washwater is discharged into sewers or storm drains. In a report by Moran (2001), however, it was concluded that applications to outdoor "impervious surfaces and applications of wettable powders appear to have the greatest potential to release the applied pesticide to surface water." The applicable studies examining the percent that runs off relative to what is applied is examined in the load section of this report.

Agricultural Use

General Trends

Chlorpyrifos and diazinon are broad-spectrum OP pesticides used to control a variety of agricultural pests, including peach twig borer, San Jose scale, and ants. In the agricultural environment, diazinon is applied to orchards during the winter dormant spray season, generally from mid-December to early March of each year, and also to prevent pest infestations during the fruit and vegetable growing season, from approximately April to September of each year. The primary use of diazinon is during the dormant season for applications with dormant oil on nut and stone fruit trees. Chlorpyrifos is used during the orchard dormant spray season to control boring insects and during the fruit and vegetable growing season to control alfalfa weevils, wireworms, rootworms, cutworms, cockroaches, ants, mites, scales, aphids, and thrips. Some of the major uses of chlorpyrifos during the irrigation season are on alfalfa and sugarbeets for worm control, and on walnuts and almonds for codling moth and twig borer control (Foe and Sheipline, 1993).

For the area of interest, diazinon is used primarily on almonds and stone fruits. Almond, peach, apricot and prune represent over 70% (52%, 11%, 6% and 5%, respectively) of the average amount applied for the years examined. Diazinon use on almonds shows a decreasing trend from 1995 through 2000. Chlorpyrifos use on almond, alfalfa, cotton and walnut represent about 85% (40%, 17%, 16% and 12%, respectively) of the average amount applied for the years examined. In both cases, these crops are not among the crops with use cancellations announced (Table 3.1).

Dormant and In-season Trends

The seasonality of chlorpyrifos and diazinon use was examined using the PUR data. Note that during the dormant season, the entire drainage area for the sub-area upstream of Salt Slough is considered, whereas only the effective drainage area for this particular sub-area is considered during the irigation season. This change in drainage area is used to account for the extremely low or no-flow conditions that exist for this reach of the SJR during the irrigation season. During storm events, runoff that reaches the river is likely a function of the magnitude and duration of the storm and antecedent conditions such as ground saturation. During the irrigation season however, only return flow and runoff from the effective drainage area has the potential to reach the river.

Dormant Season Use

Dormant season uses of diazinon and chlorpyrifos for 1995 through 2000 are summarized in Table 3.5 and Table 3.6. For purposes of extracting data, the period defined as the "dormant season" was January through March plus December of the previous year. Applications during this time period were defined as occurring during the dormant spray period. Some in-season applications may, however, also have been counted as part of the dormant period. This would be the case, for example, during periods when warm weather starts early and in-season applications were conducted in mid to late March. For the project area, use of diazinon during the dormant season is primarily for nuts and stone fruit. Sixty-two percent of diazinon applied during the time period specified is on almonds though there is a notable decrease in use on this commodity between 1999 and 2000. Stonefruits account for 29% of diazinon applied. Chlorpyrifos use during the dormant season is primarily for alfalfa and almond. These two crops account for 77% of the chlorpyrifos applied during this period. A decreasing trend in use has been observed for both crops from 1995 through 2000. Apples, grapes and peaches collectively account for 20% of the chlorpyrifos applied during this period.

Table 3.5 Summary of Dormant Season Use of Diazinon (1995 to 2000).

Note: The domant season was defined as December through March (December of the previous year and January through March of the following year).

	Diazinon Dormant Season Use (pounds of active ingredient)												
CROP	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Total**	**Average per year**	**% Average**	**Average Acreage Planted**	**% of Acreage Planted**	**Average Acreage Treated**	**Average Rate of Application (lbs/acre)**
Almond	28,803	34,851	19,032	32,984	40,213	10,589	166,472	27,745	62	21,691	33	16,128	1.72
Peach	7,202	5,845	4,508	4,752	6,431	3,966	32,704	5,451	12	9,631	15	7,668	0.71
Apricot	6,132	3,935	882	2,857	2,379	2,511	18,696	3,116	7	5,274	8	2,666	1.17
Apple	3,785	3,781	2,468	1,169	1,291	1,260	13,754	2,292	5	1,492	2	1,167	1.96
Prune	2,835	1,829	1,409	1,658	2,346	1,483	11,560	1,927	4	1,166	2	1,024	1.88
Nectarine	1,377	1,191	995	1,120	1,207	1,192	7,082	1,180	3	3,928	6	2,210	0.53
Alfalfa	2,890	3,092	186	302	0	0	6,470	1,078	2	2,772	4	2,586	0.42
Plum (including wild plums for human consumption)	1,231	930	710	761	638	826	5,096	849	2	448	1	410	2.07
Cherry	860	523	406	454	211	103	2,557	426	1	272	0.4	249	1.71
Other	331	98	300	562	121	259	1,714	286	1	17,951	28	772	0.37

Table 3.6 Summary of Dormant Season Use of Chlorpyrifos (1995 to 2000).

Note: The dormant season was defined as December through March (December of the previous year and January through March of the following year).

	Chlorpyrifos Dormant Season Use (pounds of active ingredient)												
CROP	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Total**	**Average per year**	**% Average**	**Average Acreage Planted**	**% of Acreage Planted**	**Average Acreage Treated**	**Average Rate of Application (lbs/acre)**
Alfalfa	32,715	31,410	20,806	21,428	8,890	8,621	123,870	20,645	58	34,436	68	31,845	0.65
Almond	9,931	10,629	3,963	6,660	7,699	1,709	40,591	6,765	19	4,983	10	3,999	1.69
Apple	5,283	3,557	3,491	4,378	3,303	1,762	21,774	3,629	10	3,447	7	2,018	1.80
Grapes (table)	0	507	1,770	5,643	3,378	2,300	13,598	2,266	6	1,734	3	1,129	2.01
Grapes (wine)	0	180	39	1,172	515	495	2,401	400	1	260	1	207	1.94
Peach	2,735	1,670	1,048	759	992	790	7,994	1,332	4	974	2	727	1.83
Other	499	789	562	690	1,135	828	4,503	751	2	4,478	9	4,044	0.19

In-Season Use

In-season uses of diazinon and chlorpyrifos are presented in Table 3.7 and 3.8. Use of chlorpyrifos on almonds and walnuts account for over 60% of the average amount of chlorpyrifos applied to all irrigation season crops per year. Application to cotton accounts for 16%, while application to alfalfa and corn together account for 18%. Although based on the average per year, the amount applied to almonds represents 27% of the total diazinon used during the season; there has been a significant decrease in its use from 1995 through 2000. Cantaloupes, melons and watermelons account for 29% of the amount applied, at 16%, 11% and 2%, respectively. Almond is also the highest use for both diazinon and chlorpyrifos during the irrigation season. In addition to almond, high use during the irrigation season is also reported for cotton, walnut, alfalfa and corn.

Table 3.7 Summary of In-Season Use of Diazinon (1995 to 2000).

CROP	Diazinon In Season Use (pounds of active ingredient) 1995	1996	1997	1998	1999	2000	Total	Average per year	% Average	Average Acreage Planted	% of Acreage Planted	Average Acreage Treated	Average Rate of Application (lbs/acre)
Almond	12,899	8,652	1,631	73	826	76	24,157	4,026	27	6,797	21	3,370	1.19
Cantaloupe	2,394	2,591	3,970	486	2,539	1,868	13,848	2,308	16	4,977	15	4,429	0.52
Melons	1,697	1,609	1,822	1,499	1,747	999	9,373	1,562	11	3,474	11	3,202	0.49
Apricot	2,051	1,580	892	1,027	1,529	739	7,818	1,303	9	906	3	700	1.86
Walnut (English, Persian)	1,942	1,413	1,717	991	309	1,338	7,710	1,285	9	3,465	11	763	1.68
Prune	351	414	269	2,505	1,087	1,496	6,122	1,020	7	824	3	683	1.49
Tomatoes (processing/canning)	805	1,554	195	270	797	2,325	5,946	991	7	1,374	4	1,134	0.87
Peach	818	703	194	207	127	343	2,392	399	3	3,657	11	245	1.63
Watermelons	149	210	728	0	256	87	1,430	238	2	580	2	357	0.67
All Others	1,579	1,548	1,417	1,033	1,174	2,858	9,609	1,602	11	6,583	20	2,122	0.75

Note: The in-season period was defined as April through August.

Table 3.8 Summary of In-Season Use of Chlorpyrifos (1995 to 2000)

CROP	Chlorpyrifos In Season Use (pounds of active ingredient) 1995	1996	1997	1998	1999	2000	Total	Average per year	% Average	Average Acreage Planted	% of Acreage Planted	Average Acreage Treated	Average Rate of Application (lbs/acre)
Almond	51,324	66,530	74,089	76,895	52,548	61,762	383,148	63,858	43	64,161	35	40,853	1.56
Walnut (English, Persian)	31,474	31,002	27,105	25,589	22,495	21,436	159,101	26,517	18	42,203	23	31,489	0.84
Cotton	67,516	15,719	34,474	6,137	9,152	7,429	140,427	23,405	16	28,251	15	25,457	0.92
Alfalfa	17,154	8,426	9,744	11,087	6,466	12,609	65,486	10,914	7	21,706	12	19,934	0.55
Corn (forage/fodder)	11,936	6,676	10,746	7,142	9,067	10,357	55,924	9,321	6	11,146	6	8,250	1.13
Apple	6,897	5,454	5,985	5,242	1,927	1,389	26,894	4,482	3	6,463	4	3,185	1.41
Sugarbeet	2,585	2,777	4,227	2,832	5,138	2,672	20,231	3,372	2	4,296	2	3,950	0.85
Sweet Potato	952	1,647	2,249	1,724	5,348	3,772	15,692	2,615	2	1,488	1	1,332	1.96
Asparagus	0	2,309	1,007	63	920	1,697	5,996	999	1	1,070	1	1,039	0.96
All Others	940	1012	1355	2035	1666	1969	8977	1496	1	3335	2	953	1.44

Note: The in-season period was defined as April through August.

Seasonal Application by Subarea

To determine where the highest occurrences of chlorpyrifos and diazinon agricultural uses are in the project area, use and cropping patterns were examined according to subareas.

Dormant Season

Dormant season uses of diazinon and chlorpyrifos according to subarea are presented in tables 3.9 and 3.10. The subareas with the higher percentages of diazinon use are SJR upstream of Salt Slough (45%) and the East Valley Floor (20%); these two also drain an area equal to a little over 40% of the total area drained. The three major eastside tributaries collectively account for 14% of the diazinon used and the Northwest side sub-area and the Grassland watershed sub-area account for 19% of the average diazinon used during the time period examined. Dormant season chlorpyrifos use is also highest for the SJR upstream of Salt Slough (33%) and East Valley Floor (24%). The Grassland and Northwest side subareas collectively account for 27% of average chlorpyrifos use, while the three main eastside tributaries account for the remaining 13%.

Table 3.9 Diazinon Dormant Season Use by Sub-Area.

Subareas	Acreage	Diazinon Dormant Season Annual Use (in pounds active ingredient)							% Average
		1995	1996	1997	1998	1999	2000	Average	
SJR upstream of Salt Slough	944,630	27009	25240	14439	19451	24140	11986	20378	45
Merced River	188,150	2183	3140	4668	2862	3118	1569	2923	6
Tuolumne River	161,910	2083	2727	1448	1709	3308	318	1932	4
Stanislaus River	97,280	1881	2243	1201	1943	3751	1165	2031	4
East Valley Floor	304,639	5594	13169	4809	13758	12953	3018	8884	20
Other									
Grassland	870,390	6444	3467	1419	2591	3984	590	3083	7
Northwest Side (including Orestimba Cr.)	395,910	10195	5999	2800	4487	3615	4416	5252	12
Orestimba Creek	130,560	703	92	228	480	0	1269	462	1

Table 3.10 Chlorpyrifos Dormant Season Use by Sub-Area.

Subareas	Acreage	Chlorpyrifos Dormant Season Annual Use (in pounds active ingredient)							% Average
		1995	1996	1997	1998	1999	2000	Average	
SJR upstream of Salt Slough	944,630	12364	11218	9479	18711	15035	7129	12323	33
Merced River	188,150	5815	5183	4716	4150	1352	1070	3714	10
Tuolumne River	161,910	655	1252	280	779	1178	1092	873	2
Stanislaus River	97,280	172	541	30	273	88	247	225	1
East Valley Floor	304,639	15412	15442	7859	7637	5256	3192	9133	24
Other									
Grassland	870,390	9101	6402	6177	5783	2167	2846	5413	15
Northwest Side (including Orestimba Cr.)	395,910	7810	8763	4285	4794	904	944	4583	12
Orestimba Creek	130,560	1463	1648	1261	1249	491	230	1057	3

In-season

In-season uses of chlorpyrifos and diazinon according to subarea are summarized in tables 3.11 and 3.12. In both cases, uses in the SJR upstream of Salt Slough subarea are highest relative to the other subareas. The effective drainage area for this subarea represents 14% of the total area drained. Use of diazinon in the subareas with the three major eastside inputs has decreased over the period examined. On the average, these collectively account for 10% of the diazinon used. Use of chlorpyrifos in these same subareas, on the other hand, remains more or less the same over the period examined. The three subareas of Merced River, Tuolumne River and Stanislaus River collectively account for 19% of the total area drained and 25% of the total chlorpyrifos used. The East Valley Floor accounts for 21% of the total chlorpyrifos used and 10% of the total diazinon used during the in-season.

Table 3.11 Diazinon In-Season Use By Sub-Area.

Subareas	Acreage	Diazinon In Season Annual Use (in pounds active ingredient)							% Average
		1995	1996	1997	1998	1999	2000	Average	
SJR upstream of Salt Slough (effective drainage area)	334,710	29084	11406	6554	5032	4015	37641	7967	28
Merced River	188,150	1961	464	305	65	5	0	2231	8
Tuolumne River	161,910	1364	647	286	356	25	22	450	2
Stanislaus River	97,280	479	489	96	34	697	76	381	1
East Valley Floor	304,639	6304	4537	1294	431	336	507	3798	13
Other									
Grassland	870,390	7719	7191	6750	1984	4711	3808	2914	10
Northwest Side (including Orestimba Cr.)	395,910	4035	5552	2642	2567	3413	5765	2154	7
Orestimba Creek (irrigation season)	7,039	463	71	97	263	80	897	626	2

Table 3.12 Chlorpyrifos In-Season Use By Sub-Area.

Subareas	Acreage	Chlorpyrifos In Season Annual Use (in pounds active ingredient)							% Average
		1995	1996	1997	1998	1999	2000	Average	
SJR upstream of Salt Slough (effective drainage a	334,710	16207	15417	15521	14465	244815	12142	53095	28
Merced River	188,150	24645	27003	26229	29909	20384	23410	25263	14
Tuolumne River	161,910	8415	10769	14648	10803	12364	10948	11325	6
Stanislaus River	97,280	9798	10744	8985	8251	7774	9105	9110	5
East Valley Floor	304,639	34876	30425	41981	41464	32302	37231	36380	20
Other									
Grassland	870,390	81350	30929	49943	21058	24407	23821	38585	21
Northwest Side (including Orestimba Cr.)	395,910	15073	15884	13264	12564	5458	7842	11681	6
Orestimba Creek (irrigation season)	7,039	1507	1000	1568	955	357	676	1011	1

3.5 Pesticide Load

The primary goal of calculating pesticide loads is to identify significant sources of diazinon and chlorpyrifos in the LSJR Basin by type and geographic distribution. The types of sources under consideration include. This section is broken into three major parts. The first discusses some general concepts of loads and how they are estimated. The second and third parts describe load estimates for the dormant spray and irrigation seasons, respectively. The sources considered for the dormant spray and irrigation seasons include:

- agricultural runoff
- urban runoff
- atmospheric deposition from agriculture

For each season, the amount of loading from various subareas within the Lower SJR Basin is estimated so they can be compared. An attempt is also made to relate loading to pesticide use. Lastly, agricultural and urban sources are compared and their relative impacts on stream concentrations assessed. Estimation of the historic loading from each subarea also provides a baseline to compare with the load allocations proposed in section 5 of this report.

For the different categories of sources listed above, both dissolved chlorpyrifos and dissolved diazinon are evaluated. Only dissolved loads are considered since most samples are analyzed only for dissolved concentrations, and because the water quality objectives are defined in terms of dissolved concentrations. Loads associated with pesticide adsorbed to suspended sediment particles are not considered. Because chlorpyrifos has a relatively high affinity for binding to sediment particles, it should be noted that sediments might not be insignificant to its fate and transport. The load estimates or relationships below may not be as applicable for conditions where suspended sediment concentrations are appreciably altered, as for example, in an implementation program associated with sediment control.

Load Concepts

This section discusses some general concepts of loads that are used later in estimating loads. Terminology is defined, and some general comments are made concerning how loads are estimated. The exact steps used to estimate loads for a specific source category are explained more fully in later sections.

Load estimates are useful because they allow the magnitude of different sources to be compared, and their impact on stream concentrations to be assessed. Loads can be used to estimate what percentage of a concentration measurement is derived from the various existing sources. For example, for a stream with steady flow, where source "A" is estimated as steadily contributing nine pounds of pollutant per day and source "B" is contributing one pounds per day, it can be shown that source "A" is responsible for 90 percent of the pollutant concentration, and source "B" is responsible for 10 percent of the concentration. It may be then inferred that source "A" is the primary factor contributing to a high stream contribution. Loads can also be used to predict stream concentrations for different magnitudes of flows. For non-steady processes, however, interpreting how loads affect stream concentrations is more complicated since the loads may be delivered at different times.

Loading is defined as the rate at which mass is transported at a specific stream location. Loading estimates are based on measurements of water-column pesticide concentration and flow rate at a specific location. Whereas flow rate is a measure of volume transported per time, loading is a measure of mass transported per time. Because concentration represents the mass of pesticide per volume, loading is determined by multiplying flow by concentration. If the flow is expressed as an average daily flow expressed in cubic feet per second and the concentration is expressed as micrograms per liter, the loading in terms of pounds of pesticide per day may be calculated using:

$$\text{Loading (lbs/day)} = 0.005384 \text{ x Flow (cfs) x Concentration (microgram/liter)}$$

where 0.005384 is a conversion factor. The loading rate at a specific instant in time is equal to the concentration of a grab sample multiplied by an instantaneous flow measurement at the same point in time. Sometimes instantaneous loading estimates are averaged, to determine average loading rates, such as an average monthly irrigation season loading from a tributary.

For processes that are ephemeral and event driven rather than continuous, such as with storms, it may be more meaningful to estimate the total load introduced by the event, as opposed to a loading rate. The total load is calculated by integrating (i.e. summing) the loading rate over the period of the event. Mathematically, this is expressed in terms of an integral as:

$$\text{Load} = \int_0^t \text{LoadingRate}(t)\, dt$$

or in terms of flow and concentration, the integral is:

$$\text{Load} = \int_0^t \text{Concentration}(t) \text{ x Flow(t) } dt$$

where T is the length of time of the event, and Loading Rate (t) is the loading rate at time "t". The integral represents the summation of incremental loads transported in the stream over the duration of the event. A load has units of mass, whereas loading rate has units of mass per time.

To exactly calculate a total load by integration, the concentration and flow must be known at every point in time within the time period *T*. Since this is never the case due to cost constraints associated with any field study, the concentration and flow must be estimated for times between the measurements. Some method of interpolation is often used, such as through graphing. If the loading rate is graphed versus time, the load can be interpreted as the area below the curve. Averaging techniques are also sometimes used, where the concentration over time, such as a day, is assumed based on limited measurements. An extended discussion is provided below for the exact methods used to estimate loads and loading rates for the various source categories.

Dormant Spray Season Load Estimates

This section estimates loads from agricultural and urban sources during the dormant season. The primary mechanisms of transport considered are storm runoff from agricultural fields, storm runoff from urban areas, and atmospheric transport from agricultural applications to urban areas.

Agricultural Runoff

Storm loads generally arrive as a pulse, with the duration varying from less than a day to a week or more, depending on the size of the drainage basin, and the duration of the rainfall event. For a small drainage area such as Orestimba Creek, the load is usually of short duration, generally less than two days. Figure 3.4 illustrates a typical storm runoff event at Orestimba Creek in February 2000. The majority of diazinon transport began on February 14, and ended within a twenty-four interval, well before the end of the hydrograph. In contrast, for the entire LSJR Basin, it may take one week or more for most of the loads to pass through the mouth of the Basin, located at SJR near Vernalis. Load passing SJR at Vernalis is the result of combined loads from every tributary in the basin as well as direct runoff from fields adjacent to the mainstem, all of which may arrive at different times depending on their distance from Vernalis. The arrival of loads to Vernalis at different times will tend to spread the duration of the total load. Figure 3.5 illustrates a typical runoff event at Vernalis in February 2000, which began on February 13, and continued for approximately one week.

Studies show that pesticide concentrations in SJR Basin streams usually increase and reach a maximum during the rising limb of the storm hydrograph, and then decline during the fall of the hydrograph (Kratzer, 1998). This is illustrated in Figure 3.6, where the diazinon concentration of the Tuloumne River peaked at 0.073 ìg/L on February 12, 2000, as the hydrograph was still ascending. The initially high concentration is an indication of the high amount of pesticide initially available for runoff in conjunction with an initially small amount of flow available for dilution during the rising limb of the hydrograph. As the amount of pesticide on the ground and foliage declines, and runoff increases, concentrations likewise decline. Pollutant properties will also affect the timing of peak concentrations in the storm hydrograph (Ward and Elliot, 1995). For dissolved pollutants such as diazinon, peak concentration will closely track the peak of the hydrogrpah. For more sediment bound pollutants, such as chlorpyrifos, the concentration will more likely precede the peak of the hydrograph.

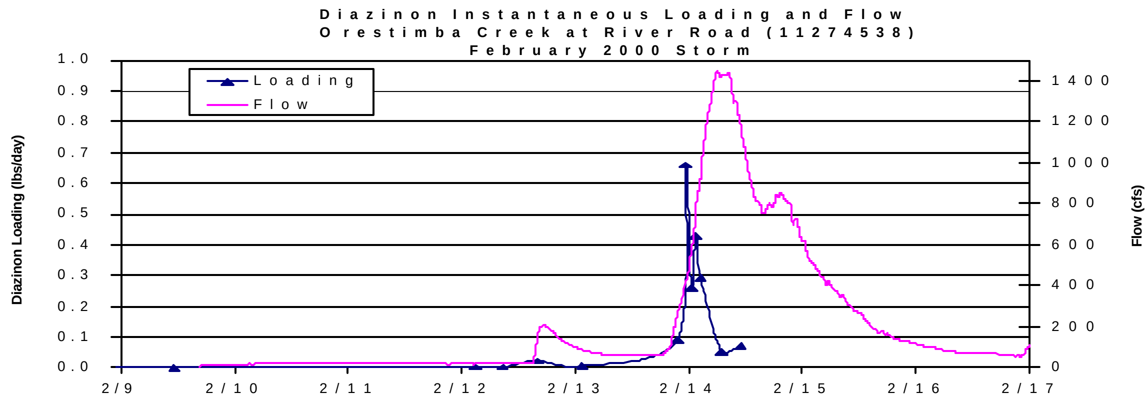


Figure 3.4 Diazinon Loading and Flow at Orestimba Creek, February 2000 Storm

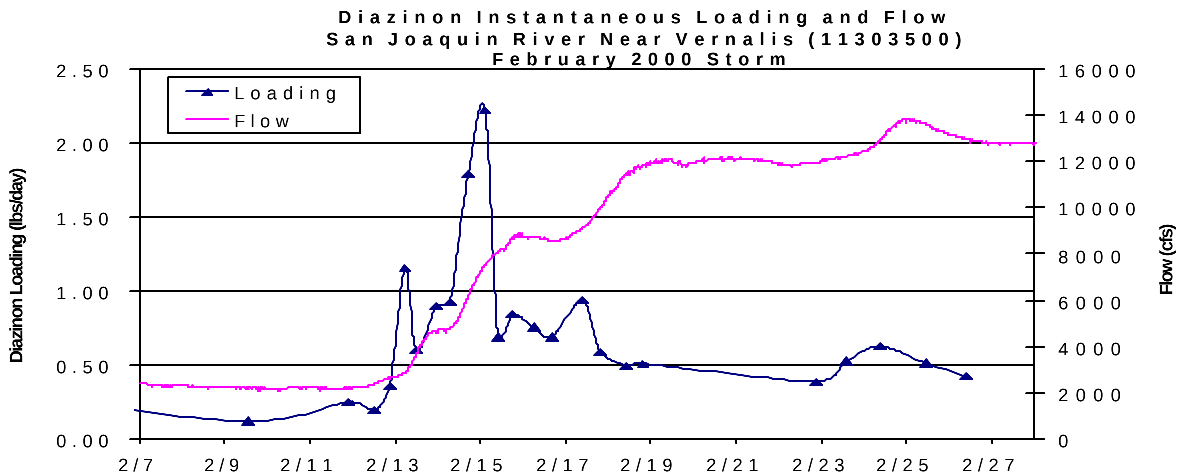


Figure 3.5 Diazinon Loading and Flow at SJR Near Vernalis, February 2000 Storm

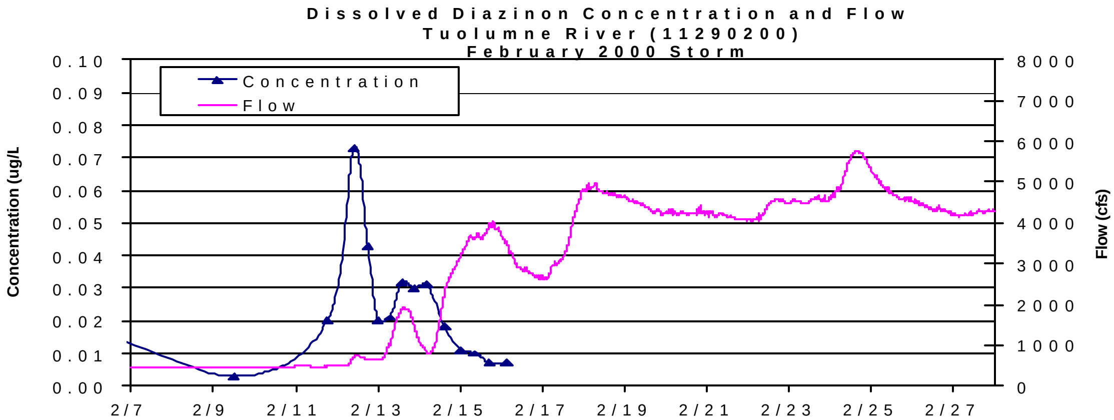


Figure 3.6 Dissolved Diazinon Concentration and Flow at Tuolumne River During February 2000

For those drainage basins where the concentration rises and declines within the course of the storm hydrograph, it appears that available pesticide is nearly washed off completely during the early stage of the storm. This implies that pesticide load may not necessarily be correlated with the size of a storm for some drainage basins; small or large storms may result in similar loads. In streams dominated by storm runoff, a smaller storm may result in more excursions of criteria if it produces a large load while providing only a small volume of runoff for dilution. Acute one-hour criteria are therefore most likely to be exceeded during the rising limb of a storm hydrograph, when instantaneous concentrations are highest.

There is some uncertainty associated with load estimates when the number of data points is limited. Designing field studies to estimate storm loads can be challenging because it requires that a sufficient number of samples be collected throughout the storm event, such that a curve can be defined. Achieving this can be difficult because it requires 24-hour sample collection at sites throughout the SJR Basin for a week or more. Sample collection must also be correctly timed with a rainfall event such that samples are collected prior, during, and after the storm hydrograph. Because of these difficult logistics, focus of monitoring studies has often been narrowed to a specific area of the basin, such as the east side tributaries and the SJR near Vernalis. For this reason, it is sometimes difficult to compare loads throughout the Basin. Not infrequently, studies have lacked sufficient number of samples to precisely define the load pulse.

Chlorpyrifos Loads During the Dormant Season

Estimates of chlorpyrifos storm loads for various storm events from 1994 to 2001 are presented in Table 3.13. All estimates here are taken from USGS published and draft reports. As indicated, data is not yet available for dormant season 2001 storm events. Loads as a percent of total basin load are presented in Table 3.14. The only complete set of load estimates currently available are for a February 2000 storm. In this storm event, the largest source of loads to the mainstem SJR is from the upstream portion of the basin as recorded at SJR near Stevinson, from the Mendota Pool to just upstream of Salt Slough. This area was responsible for 18 percent of the 1.48 pound load that passed Vernalis. Of the east side tributaries, the Tuolumne River is the largest source at 14 percent, with the Merced and Stanislaus Rivers contributing 11 percent and 7 percent, respectively. Orestimba Creek contributed only 2 percent of the total load. A large portion of the total load, 49 percent, was unaccounted for. The source of this additional load may include the East Valley Floor, the Northwest Side outside the Orestimba Creek watershed, and the Grassland Area. It may also reflect uncertainty in the data, since interpolation and best professional judgment was needed to characterize the total load passing SJR at Vernalis (Kratzer, 2001).

The load at Vernalis as a percent of amount of pesticide applied during the dry periods preceding the February 2000 storm is 0.08 percent, and 0.06 percent for a January 2000 storm (USGS 2001). The percentage for the February storm is 0.05 in the Tuolumne River Basin. Though there was no recorded agricultural application in the Stanislaus River and Orestimba Creek watersheds in 2000, these two basins had measurable loads. This may reflect unreported use, unaccounted for sources such as from atmospheric deposition, or both. The maximum instantaneous loading in February 2000 range from 0.040 pounds per day for Orestimba Creek to 0.088 pounds per day for Merced River (table 3.15).

Table 3.13 Chlorpyrifos Storm Loads in Lower SJR Basin (pounds)

		1994 [A]		2000 [B]		2001 [C]	
Drainage Basin	**Area (acres)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/6-2/8)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/9-2/14)**	**Storm 1 (1/26-1/28)**	**Storm 2 (2/24-2/26)**
SJR near Stevinson	944,530	N/A	N/A	N/A	0.27	*	*
Merced River at River Road	188,100	N/A	*	N/A	0.16	*	*
Tuolumne River at Shiloh Road	161,640	N/A	*	N/A	0.20	*	*
Stanislaus River at Caswell SP	97,390	N/A	*	N/A	0.10	*	*
East Valley Floor	296,110	N/A	N/A	N/A	N/A	N/A	N/A
Orestimba Creek at River Road	6,900	N/A	N/A	N/A	0.02	*	*
Other Drainage Basins**		N/A	*	N/A	0.73	*	*
Total (Vernalis):	2,944,800	N/A			1.48		

N/A = not available
***estimated as Vernalis load minus measured loads at tributaries and upstream location*
**values will be computed in final draft report*
A – Kratzer/USGS 1998, B – Kratzer/USGS 2001 preliminary, C – Kratzer/USGS 2001 preliminary

Table 3.14 Percent Contribution of Chlorpyrifos Storm Loads in Lower SJR Basin

		1994 [A]		2000 [B]		2001 [C]	
Drainage Basin	**Area (acres)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/6-2/8)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/9-2/14)**	**Storm 1 (1/26-1/28)**	**Storm 2 (2/24-2/26)**
SJR near Stevinson	944,530	N/A	N/A	N/A	18%	*	*
Merced River at River Road	188,100	N/A	*	N/A	11%	*	*
Tuolumne River at Shiloh Road	161,640	N/A	*	N/A	14%	*	*
Stanislaus River at Caswell SP	97,390	N/A	*	N/A	7%	*	*
East Valley Floor	296,110	N/A	N/A	N/A	N/A	N/A	N/A
Orestimba Creek at River Road	6,900	N/A	N/A	N/A	1%	*	*
Other Drainage Basins**		N/A	*	N/A	49%	*	*
Total (Vernalis):	2,944,800	N/A			100%		

NA = not available
***estimated as Vernalis load minus measured loads at tributaries and upstream location*
**values will be computed in final draft report*
A – Kratzer/USGS 1998, B – Kratzer/USGS 2001 preliminary, C – Kratzer/USGS 2001 preliminary

Table 3.15 Maximum Instantaneous Storm Loading of Chlorpyrifos in LSJR Basin (pounds/day)

		1994 [A]		2000 [B]		2001 [C]	
Drainage Basin	**Area (acres)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/6-2/8)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/9-2/14)**	**Storm 1 (1/26-1/28)**	**Storm 2 (2/24-2/26)**
SJR near Stevinson	944,530	N/A	N/A	N/A	0.072	*	*
Merced River at River Road	188,100	N/A	*	N/A	0.088	*	*
Tuolumne River at Shiloh Road	161,640	N/A	*	N/A	0.081	*	*
Stanislaus River at Caswell SP	97,390	N/A	*	N/A	0.059	*	*
East Valley Floor	296,110	N/A	N/A	N/A	N/A	N/A	N/A
Orestimba Creek at River Road	6,900	N/A	N/A	N/A	0.040	*	*
Other Drainage Basins**		N/A	*	N/A	N/A	*	*
Total (Vernalis):	2,944,800	N/A			0.387		

N/A = not available
***estimated as Vernalis load minus measured loads at tributaries and upstream location*
**values will be computed in final draft report*
A – Kratzer/USGS 1998, B – Kratzer/USGS 2001 preliminary, C – Kratzer/USGS 2001 preliminary

Maximum chlorpyrifos concentrations are summarized in Table 3.16. Concentrations which exceeded the CDFG acute criteria of 0.025 micrograms per liter, are in bold. A sample may not have been collected when the stream concentration actually peaked, especially if few samples were collected. Thus, the highest measured concentrations here are likely to be below the actual maximum. CDFG acute criteria were exceeded mainly during 1994 storms. During the 2000 storm season, the acute criterion was exceeded only in SJR near Stevinson in February 2000.

Table 3.16 Maximum Observed Storm Chlorpyrifos Concentrations in Lower SJR Basin (micrograms per liter)

		1994 [A]		2000 [B]		2001 [C]	
Drainage Basin	**Area (acres)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/6-2/8)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/9-2/14)**	**Storm 1 (1/26-1/28)**	**Storm 2 (2/24-2/26)**
SJR near Stevinson	944,530	N/A	N/A	0.015	**0.073**	0.007	<0.005
Merced River at River Road	188,100	**0.097**	**0.054**	0.007	0.012	0.016	0.003
Tuolumne River at Shiloh Road	161,640	**0.032**	0.013	0.018	0.008	0.009	<0.005
Stanislaus River at Caswell SP/Ripon CA	97,390	0.015	<0.004	0.010	0.007	0.007	0.011
Orestimba Creek at River Road	6,900	N/A	N/A	0.006	0.011	0.003	0.006
SJR Near Vernalis	2,944,800	**0.029**	0.017	0.012	0.016	0.01	<0.005

N/A = Not Available
A – Kratzer/USGS 1998, B – Kratzer/USGS 2001 preliminary, C – Kratzer/USGS 2001 preliminary
(Concentrations exceeding 0.025 microgram per liter acute toxic criteria are in bold)

Diazinon Loads during the Dormant Season

Diazinon load estimates for various storm events from 1994 to 2001 are summarized in table 3.17. As indicated, data is not yet available for dormant season 2001 storm events. Loads as a percent of total basin load are presented in Table 3.18. As for chlorpyrifos, the largest load detected is from the upstream portion of the basin, in the SJR near Stevinson; this site accounts for 28 percent of the total 4.92 pounds of diazinon estimated for Vernalis. The Tuolumne River was the largest east side tributary source with 15 percent. The Merced River and Stanislaus Rivers account for six and 12 percent, respectively. Orestimba Creek accounts for three percent of the total load. The total unaccounted for load is 37 percent. As for chlorpyrifos, there is some uncertainty with these estimates.

Table 3.17 Diazinon Storm Loads In Lower SJR Basin (pounds)

		1994 [A]		2000 [B]		2001 [C]	
Drainage Basin	**Area (acres)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/6-2/8)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/9-2/14)**	**Storm 1 (1/26-1/28)**	**Storm 2 (2/24-2/26)**
SJR near Stevinson	944,530	N/A	N/A	N/A	1.37	*	*
Merced River at River Road	188,100	N/A	1.50	N/A	0.28	*	*
Tuolumne River at Shiloh Road	161,640	N/A	1.80	N/A	0.74	*	*
Stanislaus River at Caswell SP	97,390	N/A	0.10	N/A	0.60	*	*
East Valley Floor	296,110	N/A	N/A	N/A	N/A	*	*
Orestimba Creek at River Road	6,900	N/A	N/A	N/A	0.13	*	*
Other Drainage Basins**		N/A	4.40	N/A	1.80	*	*
Total (Vernalis):	2,944,800	19.60	7.80	N/A	4.92	*	*

N/A = Not Available
***estimated as Vernalis load minus measured loads at tributaries and upstream location*
**values will be computed in final draft report*
A – Kratzer/USGS 1998, B – Kratzer/USGS 2001 preliminary, C – Kratzer/USGS 2001 preliminary

Table 3.18 Percent Contribution of Diazinon Storm Loads In Lower SJR Basin

		1994 [A]		2000 [B]		2001 [C]	
Drainage Basin	**Area (acres)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/6-2/8)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/9-2/14)**	**Storm 1 (1/26-1/28)**	**Storm 2 (2/24-2/26)**
SJR near Stevinson	944,530	N/A	N/A	N/A	28%	*	*
Merced River at River Road	188,100	N/A	19%	N/A	6%	*	*
Tuolumne River at Shiloh Road	161,640	N/A	23%	N/A	15%	*	*
Stanislaus River at Caswell SP	97,390	N/A	1%	N/A	12%	*	*
East Valley Floor	296,110	N/A	N/A	N/A	N/A	N/A	N/A
Orestimba Creek at River Road	6,900	N/A	N/A	N/A	3%	*	*
Other Drainage Basins**		N/A	56%	N/A	37%	*	*
Total (Vernalis):	2,944,800	100%	N/A	100%	*	*	N/A

N/A = Not Available
***estimated as Vernalis load minus measured loads at tributaries and upstream location*
**values will be computed in final draft report*
A – Kratzer/USGS 1998, B – Kratzer/USGS 2001 preliminary, C – Kratzer/USGS 2001 preliminary

The load at Vernalis as a percent of application during the dry periods preceding the storm is 0.13 percent, and 0.05 percent for a storm in a January 2000 storm. This compares with 0.05 percent during two storms in January and February 1994 (Kratzer, 1999). The load for the Tuolumne River Basin, as a percent of application, is 0.05. As for chlorpyrifos, despite no recorded applications in the Stanislaus River and Orestimba Creek watersheds for January 2000, these two basins had measurable loads. This may reflect unreported use, drift, or both. Maximum instantaneous loading rates are shown in table 3.19. The only estimates currently available are for the storm in February 2000. Instantaneous storm loads ranged from 0.120 pounds per day for the Merced River to 0.66 pounds per day for Orestimba Creek. Maximum instantaneous loading in the SJR near Vernalis was 2.10 pounds per day.

Table 3.19 Maximum Instantaneous Storm Loading of Diazinon in Lower SJR Basin (pounds/day)

		1994 [A]		2000 [B]		2001 [C]	
Drainage Basin	**Area (acres)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/6-2/8)**	**Storm 1 (1/23-1/25)**	**Storm 2 (2/9-2/14)**	**Storm 1 (1/26-1/28)**	**Storm 2 (2/24-2/26)**
SJR near Stevinson	944,530	N/A	N/A	N/A	0.384	*	*
Merced River at River Road	188,100	N/A	*	N/A	0.120	*	*
Tuolumne River at Shiloh Road	161,640	N/A	*	N/A	0.368	*	*
Stanislaus River at Caswell SP	97,390	N/A		N/A	0.250	*	*
East Valley Floor	296,110	N/A	N/A	N/A	N/A	*	*
Orestimba Creek at River Road	6,900	N/A	N/A	N/A	0.66	*	*
Other Drainage Basins**		N/A	*	N/A	N/A	*	*
Total (Vernalis):	2,944,800	*	*	N/A	2.10	*	*

N/A = Not Available
***estimated as Vernalis load minus measured loads at tributaries and upstream location*
**values will be computed in final draft report*
A – Kratzer/USGS 1998, B – Kratzer/USGS 2001 preliminary, C – Kratzer/USGS 2001 preliminary

The highest diazinon concentrations measured during storm runoff events are shown in table 3.20. A sample may not have been collected when the stream concentration actually peaked, especially if few samples were collected. Thus, the highest measured concentrations and instantaneous loads here are likely to be below the actual maximum. In contrast to chlorpyrifos, the acute criteria were frequently exceeded. Criteria were exceeded in each of the three years at the two main stem SJR sites: SJR near Stevinson and SJR near Vernalis. The magnitude with which criteria were exceeded was most severe in the January storms. This may be because less diazinon was available for the February storm, after the January wash-off.

Table 3.20 Maximum Diazinon Concentrations in Lower SJR Basin (micrograms per liter)

Drainage Basin	Area (acres)	1994 [A] Storm 1 (1/23-1/25)	1994 [A] Storm 2 (2/6-2/8)	2000 [B] Storm 1 (1/23-1/25)	2000 [B] Storm 2 (2/9-2/14)	2001 [C] Storm 1 (1/26-1/28)	2001 [C] Storm 2 (2/24-2/26)
SJR near Stevinson	944,530	N/A	N/A	**0.150**	**0.089**	**0.289**	**0.13**
Merced River at River Road	188,100	**0.61**	**0.23**	0.042	0.014	**0.435**	0.037
Tuolumne River at Shiloh Road	161,640	**2.9**	**0.92**	**0.092**	0.073	0.201	0.007
Stanislaus River at Caswell SP	97,390	0.072	0.054	0.030	0.054	**0.083**	0.026
Orestimba Creek at River Road	6,900	N/A	N/A	**0.183**	**0.300**	0.019	0.032
SJR Near Vernalis	2,944,800	**0.288**	**0.34**	**0.094**	0.075	**0.235**	0.013

N/A = Not Available
A – Kratzer/USGS 1998, B – Kratzer/USGS 2001 preliminary, C – Kratzer/USGS 2001 preliminary
(Exceedances of 0.08 microgram per liter acute toxic criteria are in bold)

Urban And Atmospheric Loads

As shown in the pesticide use section, there is significant reported urban diazinon and chlorpyrifos use. There are additional non-reported urban uses. The major urban areas in the LSJR Basin are all east of the San Joaquin River. The five largest cities are Modesto, Turlock, Atwater, Merced, and Madera. Modesto is the largest city, comprising 36% of the total population in the project area, and is likely to be the most significant urban source. Modesto drains primarily into the Tuolumne River. Table 3.21 shows the population of major cities in LSJR.

Table 3.21 Population of Major Cities in Lower SJR Basin

City	Population	Primary Drainage Basin(s)
Modesto	184,600	Stanislaus/East Valley Floor/Tuolumne
Merced	62,800	SJR above Salt Slough
Turlock	51,900	East Valley Floor
Ceres	32,400	East Valley Floor
Atwater	22,250	Merced/SJR above Salt Slough
Los Banos	22,200	Grasslands

A USGS study examining agricultural and urban land uses in the Tuolumne River basin was conducted during two storm events in 1994 and 1995 (Kratzer, 1998). About a third of the City of Modesto discharges stormwater to surface water and the remaining two-thirds discharges stormwater to groundwater via dry wells (City of Modesto, 1993). Storm runoff samples from agricultural areas were collected during a February storm in 1994 while storm runoff samples from urban areas were collected during a February 1995 storm. Agricultural and urban loads were therefore not directly compared. The study concluded, however, that the transport of pesticides (including chlorpyrifos, diazinon as well as metolachlor, napropamide and simazine) from agricultural areas exceeded transport from urban areas in the Tuolumne River Basin (Kratzer, 1998).

The USGS has also monitored storm runoff from the McHenry storm drain in Modesto while simultaneously collecting composite rain samples at four sites in the Modesto metropolitan area for a January 2001 storm event. Rain sample data was collected to determine the contribution of atmospheric deposition. Although no firm conclusions can be made from one storm event, preliminary results indicate that pesticides in rainfall can significantly contribute to the pesticide loads observed in runoff (Majewski, personal communication, 2002). This implies that loads monitored from urban areas may have significant contributions from agricultural sources. The USGS atmospheric deposition study in the SJR Basin is continuing and preliminary 2002 rainfall data from agricultural and urban sites suggest the concentration of diazinon and chlorpyrifos detected in rainfall is correlated to agricultural spraying (Kratzer, 2002).

Increases in diazinon concentrations detected in rainfall collected from agricultural sites coincide with the dormant spray season, and increases in chlorpyrifos concentrations coincide with dormant spray as well as alfalfa spraying in early March. The trend in monitoring data collected from the urban site in downtown Modesto appears to be similar to that from agricultural sites, suggesting that the diazinon or chlorpyrifos detected in the rain in the urban site is more likely due to agricultural than urban application. The results from a recent study in the Sacramento metropolitan area that analyzed air samples for a variety of pesticides suggest that agricultural to urban atmospheric drift of pesticides does occur, but urban use is also a potential source. No conclusions can be drawn about the significance of airborne pesticide movement from agricultural to urban areas until more details are obtained as to where and when non-agricultural pesticide use occurs (Majewski and Baston, 2002).

This information suggests that urban contributions to the mainstem SJR may be relatively small. The Tuolumne River Basin was estimated to contribute 15% of the total chlorpyrifos load at SJR near Vernalis, and between 15 and 23% of the total diazinon load at SJR near Vernalis. If it is assumed that less than half of this is contributed from urban areas as would be consistent with the study where transport of pesticides from agricultural areas exceeded transport from urban areas (Kratzer, 1998), and of this, a significant fraction is derived from atmospheric transport from agricultural areas as suspected in the preliminary atmospheric deposition study, then urban sources likely account for a relatively small contribution of loads to the mainstem SJR. For example, if half of the Tuolumne River loads is from urban areas, and half of this is derived from agricultural atmospheric deposition, this implies that the city of Modesto contributes about 3.75% (3.75% = 0.5 x 0.5 x 15%) of the total chlorpyrifos load, and 3.75 to 5.75% of the total diazinon load (5.75% = 0.5 x 0.5 x 23%). Furthermore, because Modesto is by far the largest city in the SJR Basin, representing about 36 percent of the total SJR Basin population, the total urban contribution to the mainstem SJR is likely small. If other cities are assumed to generate a similar pesticide load per capita, this would imply that the total urban load to the SJR Basin is about ten percent (10% = 3.75% / 0.36) for chlorpyrifos, and about ten to16 percent (16% = 5.75% / 0.36) for diazinon. Similarity of per capita loads to Modesto depends also on other factors, including similarity of drainage systems to Modesto, in which two-thirds of stormwater is discharged to ground water by way of dry wells, and the other third to surface water.

More information is needed to rigorously quantify the urban pesticide load contribution to the LSJR. Preliminary analysis, however, suggests that urban sources are not insignificant, although they are relatively small compared to agricultural contributions

Irrigation Season Load Estimates

Most monitoring during the irrigation season has occurred at the SJR near Vernalis, Orestimba Creek, and to a lesser extent in the Merced River. Irrigation season loads are estimated for these three major sites for the period from May through August. Rainfall records were reviewed to assure no major storms occurred during this period. Although the latter half of April and September are considered part of the irrigation season, they are not included in the estimates to prevent possible storm loads from affecting irrigation loading estimates.

Water samples with concentrations lower than the method detection limit, must be accounted for to avoid underestimating loads. Ignoring non-detects can potentially lead to an underestimate of the irrigation season load since low concentration measurements would be selectively removed. Estimating non-detected concentrations as zero will underestimate the load, whereas estimating it at the detection limit will overestimate the load. In this analysis, non-detects for both chlorpyrifos and diazinon are assumed to equal one half the concentration of the method detection limit, provided the detection limit is at or below 0.01 ìg/L. Non-detects with detection limits above 0.01 ìg/L, are not used since this is usually above the observed concentrations, and using them could introduce potentially large errors. The data was inspected visually to make sure the estimated non-detect concentrations follow the pattern made by detected concentrations on a time-series plot. For samples with high detection limits that are sometimes above the chronic criteria, a reliable estimate could not be made because the range of uncertainty was too high; this data was therefore not used.

Continuous measurements of pesticide concentrations are not available because of the substantial costs. Loading estimates must therefore be based on a limited number of measurements, introducing uncertainty. For the irrigation season, daily loading was computed based on the concentration times the daily average flow rate, as published by the USGS and DWR. This estimate is justified if the concentration does not fluctuate much over the course of a day. Flows in main stem river sites are relatively constant but smaller drainages such as Orestimba Creek may have some diurnal fluctuation as a function of irrigation. The degree of fluctuation has not been tested and in this analysis, it is assumed that the fluctuation is not significant. Any bias is unlikely for the mainstem SJR, where diurnal fluctuations are diminished due to the mixing involved.

An average monthly loading rate for the irrigation season was estimated using the following steps. First, daily average loading rates were computed by multiplying the dissolved concentration (or average concentration if multiple grab samples were taken on a particular day) by the daily average flow, giving pounds per day. These values were used to determine monthly arithmetic averages for those months where data is available, with units kept in pounds per day. An average irrigation season load was then estimated by arithmetically averaging these monthly average values. Monthly averages were computed first rather than directly taking an average of all points during the irrigation season, to prevent overly biasing the total irrigation season average with those months where many samples were collected. Thus, each month with measurements carries equal weight in the total irrigation season average.

Chlorpyrifos

Tables C1 through C3 in Appendix C of the SJR Diazinon and Chlorpyrifis TMDL Source Analysis report present the values used to compute the irrigation season loading for each year. Some years have more data points than others, and thus will allow for more reliable estimates of a total irrigation season load. Years with less than three data points were not used. For those years with only three data points, the values are in parenthesis to indicate there is more uncertainty in the estimate.

Estimates of the average irrigation season loading of chlorpyrifos from May to August are shown in table 3.22. Percent load contributions in terms of total loading at Vernalis are shown in table 3.23. The Merced River drainage basin has accounted for ten to 15 percent of the total loading in the SJR near Vernalis, and on average has accounted for 12 percent. Orestimba Creek has accounted for one to seven percent of the total Vernalis loading, and on average has been three percent.

Table 3.22 Irrigation Season Chlorpyrifos Loads in SJR Basin (pounds per day)

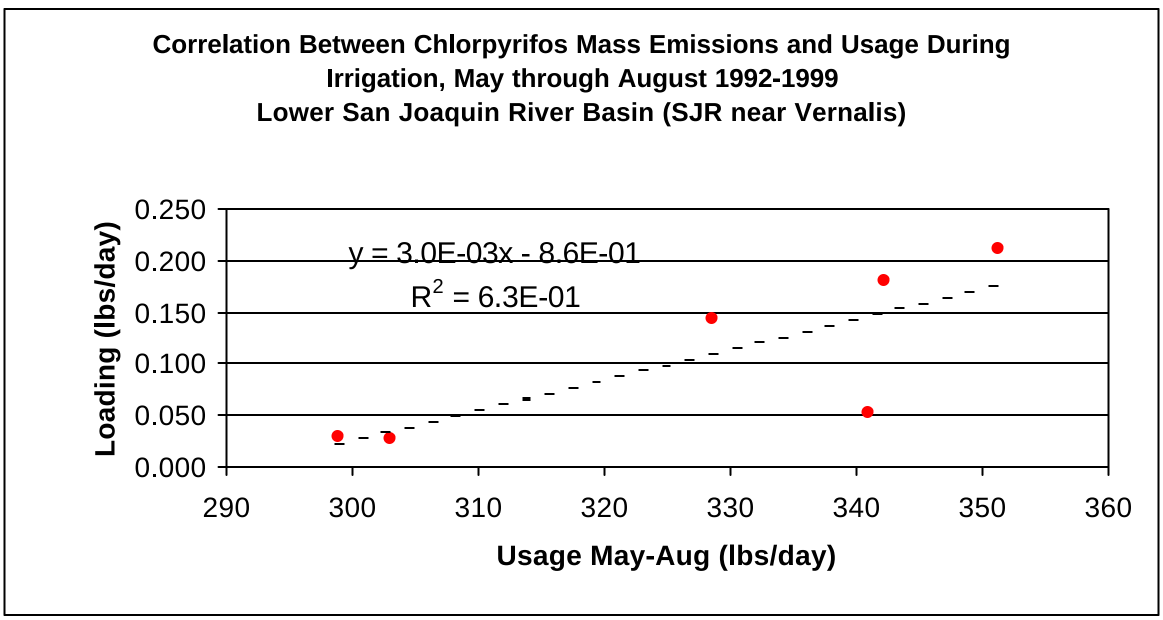
Drainage Basin	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
SJR near Stevinson											
Merced River at River Road			0.022				0.020	0.030	0.006	0.007	0.017
Tuolumne River at Shiloh Road											
Stanislaus River at Caswell SP											
East Valley Floor											
Orestimba Creek at River Road		0.002	0.002			0.008	0.003	0.018	0.001	0.004	0.006
Other Drainage Basins**		0.027	0.119				0.156	0.162	0.044	0.053	0.094
Total (Vernalis):		0.028	0.143	0.026			0.180	0.210	0.051	0.064	0.100
Application (lbs):											
Percent Runoff:											

Table 3.23 Percent Contribution of Irrigation season Chlorpyrifos Loads in SJR Basin

Drainage Basin	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
SJR near Stevinson											
Merced River at River Road			15.1%				10.9%	14.3%	11.4%	10.2%	12.4%
Tuolumne River at Shiloh Road											
Stanislaus River at Caswell SP											
East Valley Floor											
Orestimba Creek at River Road		5.5%	1.4%				1.9%		2.1%	6.9%	3.0%
Other Drainage Basins**		94.5%	83.5%				87.2%	77.1%	86.5%	82.9%	73.1%
Total (Vernalis):	100%	100%	100%		100%	100%	100%	100%	100%	100%	100%
Application (lbs):											
Percent Runoff:											

The magnitude of chlorpyrifos loading depends on a number of factors including amount of pesticide applied. As may be expected, there is some correlation between the amount applied and the amount that is washed off. Figure 3.7 presents a correlation between average irrigation season loading and amount applied in the basin. The correlation suggests that an increase in application of one hundred pounds per day applied in the basin has yielded approximately a 0.3 pound per day increase in irrigation season loading.

Figure 3.7 Correlation Between Chlorpyrifos Mass Emissions and Usage 1992-1999



In contrast to the dormant season, concentration and loading in the SJR near Vernalis remain relatively constant through the irrigation season (Figure 3.8). In contrast, Orestimba Creek, has considerable fluctuation in loading (Figure 3.9) Fluctuation in concentration and load in Orestimba Creek are due to fluctuating irrigation return flows, since there is no base flow during the summer. Flow in the relatively small Orestimba Creek basin is highly influenced by individual irrigation flows. In contrast, the loads from the entire LSJR Basin near Vernalis, are combined and averaged, and influences of individual return flows are dampened. A full set of time-series graphs of concentration, loading, pesticide use and flow for the Orestimba Creek, Merced River, and SJR near Vernalis, are presented in Appendix D of the Diazinon and Chlorpyrifos Source Analysis Report for the SJR Basin.

Figure 3.8 Chlorpyrifos Concentration, Application and Flow in San Joaquin River Near Vernalis 2000

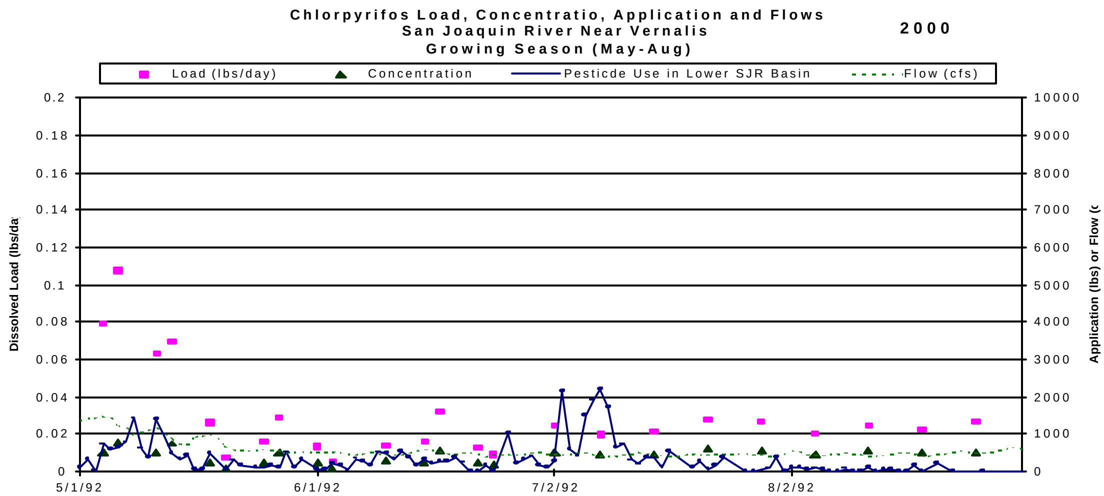
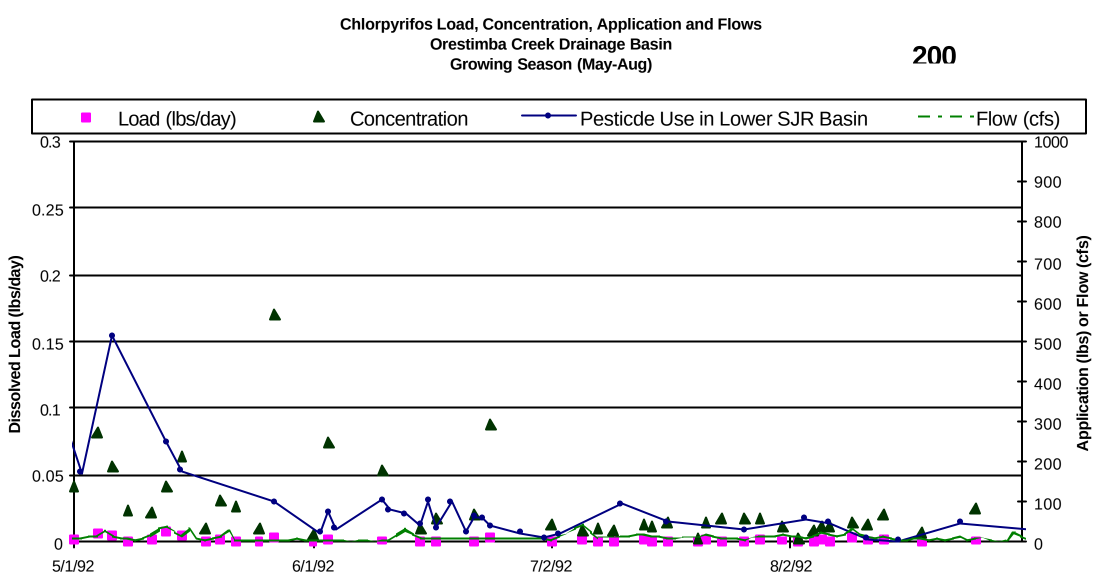


Figure 3.9 Chlorpyrifos Load, Concentration, Application and Flow in Orestimba Creek, 2000



Diazinon

Estimates of the average irrigation season loading of diazinon from May to August are shown in table 3.24. Percent load contributions in terms of total loading at Vernalis are shown in table 3.25. The Merced River drainage basin has accounted for one to 14 percent of the total loading in the SJR near Vernalis, and on average has accounted for four percent. Orestimba Creek has accounted for one to 17 percent of the total Vernalis loading, and on average has been five percent.

Table 3.24 Irrigation Season Diazinon Loads in SJR Basin (pounds per day)

Drainage Basin	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
SJR near Stevinson											
Merced River at River Road			0.009				0.002	0.010	0.002	0.003	0.004
Tuolumne River at Shiloh Road											
Stanislaus River at Caswell SP											
East Valley Floor											
Orestimba Creek at River Road		0.011	0.006			0.022	0.001	0.004	0.001	0.012	0.007
Other Drainage Basins**		0.053	0.466				0.065	0.058	0.141	0.123	0.129
Total (Vernalis):	0.092	0.064	0.480	0.017			0.068	0.072	0.145	0.138	0.135
Application (lbs):											
Percent Runoff:											

Table 3.25 Percent Contribution of Irrigation Season Diazinon Loads in SJR Basin

Drainage Basin	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
SJR near Stevinson											
Merced River at River Road			1.8%				3.2%	13.6%	1.5%	2.4%	4.5%
Tuolumne River at Shiloh Road											
Stanislaus River at Caswell SP											
East Valley Floor											
Orestimba Creek at River Road		17.3 %	1.2%				1.9%	5.6%	1.0%	8.4%	5.1%
Other Drainage Basins**		82.7 %	97.0 %				94.9 %	80.8%	97.5 %	89.2 %	90.3%
Total (Vernalis):	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Application (lbs):											
Percent Runoff:											

Atmospheric Deposition

The USGS is currently conducting a dry deposition study, with six sampling sites around the Modesto area. Sites are both agricultural and urban. Sampling will be expanded in August 2002, and sampling will be conducted for both wet and dry deposition. Results have not yet been published.

Groundwater

Groundwater transport of chlorpyrifos and diazinon is unlikely to represent a significant load to the river. Although it may be important for some pesticides, which persist in the environment for very long periods, such as DDT, it is unlikely for chlorpryifos or diazinon. The half-life of both pesticides, which are on the order of months, is much less than the residence time in the shallow groundwater table, which will be on the order of years. Additionally, the affinity of chlorpyrifos for binding onto sediment particles should minimize its transport through soil. The USGS has reported very low (0.01 to 0.03 ìg/L) levels of diazinon and chlorpyrifos in groundwater and they have not been confirmed in groundwater monitoring studies conducted by the CDPR (C. Nordmark, pers. comm.). This pathway is not believed to be a major source of OP contamination.

3.6 Conclusions

Sources of diazinon and chlorpyrifos are widely distributed throughout the LSJR Basin. Additional information on pesticide concentrations and loads for the dormant and irrigation seasons in both 2001 and 2002 was not available at the time this report was completed. This report will be appended when this data is available. This additional information and the data presented here show that there are detectable concentrations and loads of diazinon and chlorpyrifos from all subareas in both the dormant and irrigation season. Urban sources account for approximately ten percent of chlorpyrifos and ten to 16 percent of diazinon load in the TMDL project area during the dormant period. Remaining loads are attributable to agricultural sources.

Peak concentrations and loads occur during the dormant season. In particular, concentrations, and sometimes loads, are highest during the rising limb of the storm hydrograph. Acute criteria for diazinon and chlorpyrifos are therefore most likely to be exceeded during the rising limb of storm hydrographs. Acute and chronic criteria are exceeded, and loads remain high, for several days following the peak of the hydrograph. Sources of diazinon and chlorpyrifos loads during the dormant season are widely distributed in the basin. Recent dormant season storm data shows the Merced, Tuolumne, and Stanislaus Rivers account for a total of 31 percent of the total observed diazinon load and 32 percent of the total observed chlorpyrifos load at Vernalis. Orestimba Creek, which represents only a small percent of the total loading from the Northwest Side, accounted for three and one percent of the diazinon and chlorpyrifos load at Vernalis, respectively.

Though irrigation season loading data is more sparse than dormant season data, available data suggests that sources of diazinon and chlorpyrifos loads are widely distributed in the basin. The Merced River has accounted for, on average, approximately 12 percent of the total observed chlorpyrifos load, and four percent of the diazinon load at Vernalis during five seasons from 1993 through 2000. Orestimba Creek accounted for seven and three percent of the diazinon and chlorpyrifos load at Vernalis, respectively.

4.0 LINKAGE ANALYSIS

This linkage analysis provides the basis for determining the loads of diazinon and chlorpyrifos that can be discharged to various reaches of the SJR while still attaining the numeric target. This assimilative capacity is calculated by multiplying the numeric target by the anticipated flow in the various river reaches. This section describes the methods used to estimate the anticipated flow conditions for the river reaches and from these, to calculate the total assimilative capacity of the reaches. Total assimilative capacity provides the framework upon which load allocation calculations in section 5.0 are based.

4.1 Method Used

In the absence of detailed information on pollutant transport mechanisms, a hydrologically based modeling approach is used here to determine the full assimilative capacity of the SJR for various reaches. This approach requires only an estimate of the expected minimum flow conditions, or design flows, for the river reaches. The approach is adapted from USEPA methods for calculating design flows for water quality based effluent limits (USEPA, 1986). The method is similar to that used for estimating assimilative capacity in a TMDL for selenium in the San Joaquin River (Karkoski, 1994; McCarthy and Grober, 2001).

4.2 Assumptions

Several implicit and explicit assumptions must be made to conduct the linkage analysis. These assumptions include consideration of:

- Pollutant properties
- Criteria specifications
- Seasons of Use
- Flow Regimes
- Site Selection
- Additivity

<u>Pollutant Properties</u>

It is assumed that both diazinon and chlorpyrifos are conservative substances that will undergo insignificant degradation or transformations during the relatively short time periods over which diazinon and chlorpyrifos are transported.

<u>Criteria specifications</u>

The recommended target for diazinon and chlorpyrifos are based on CDFG criteria that have a specified numeric concentration, averaging period, and allowable rate of excursion (an excursion rate is the frequency with which a criteria is exceeded). All three factors are considered in the linkage analysis. The numeric criteria are the values that will be applied to the estimated flow regime. The averaging period is the duration over which a flow regime is calculated. The CDFG chronic criteria, for example, are stated in the form of four-day averages. Four-day average flows will therefore be used to determine design flows. The CDFG acute criteria are stated in the form of a maximum one-hour concentration. The daily average flow, however, will be used to calculate loading capacity for the acute criteria, since hourly flows are not extremely variable in the SJR and it would be impractical to monitor for compliance for periods shorter than one day duration. Finally, all the criteria specify an allowable one in three year rate of excursion of the numeric concentration. This excursion rate is used to identify the design flow with the appropriate anticipated rate of return.

Seasons of Use

The source analysis section has shown that there are two seasons of diazinon and chlorpyrifos use in the SJR Basin: irrigation season and dormant season. For the purposes of calculating assimilative capacity, the dormant season is defined as December through February and the irrigation season as the remaining months of March through November. This linkage analysis will present separate estimates of loading capacity for each season, with the assumption that each is the only season of use. The analysis will also present an alternate loading capacity, with the assumption that there are two seasons of use. This alternative loading capacity allows for only half of the allowable excursions from the numeric concentrations for each use season. This preserves the allowable one in three year excursion rate for two seasons of use. The methods used to estimate loading capacity for each season, however, are similar.

Flow Regimes

Design flows for this TMDL are based upon only the most recent 22-year record from 1980 through 2001. Although flow data is available for a longer time period in the SJR Basin, the data was not used because there have been major changes in LSJR hydrology. The most significant change is completion of New Melones Reservoir in 1979; the additional storage provided by this reservoir has changed the pattern of flows in the SJR near Vernalis. Only the last 22 years is therefore representative of the current level of development of the SJR Basin. This period contains some of the most critically low flow conditions on record. The lowest of the low flow conditions that will control selection of design flows have therefore been considered. A flow record of longer duration, with only higher flows, would have little effect on design flow calculations as will be further discussed under *Considerations* in section 4.4.

Site Selection

Six sites were selected to represent flow regimes for six reaches of the LSJR. Design flows and load limits were estimated for these six sites. It was assumed that each of these six sites sufficiently represented the flow regimes for six reaches and that if targets were met at the each site, they would also be met in the entire reach.

Additivity

As explained in the target analysis, the toxic effects of diazinon and chlorpyrifos are additive. Although individual load allocations are presented for diazinon and chlorpyrifos, individual load limits for each must be reduced to account for this additivity.

4.3 Method Description

Calculation of the full assimilative capacity of the various reaches was calculated using the following steps:

- Identify the sites and seasons of interest
- Select the triggering storm event and flow averaging period for diazinon and chlorpyrifos
- Assemble and process the rainfall and flow data for the seasons and sites of interest
- Select and process flows that occur during periods and events of interest
- Select design flow
- Calculate the total allowable load

Sites and Seasons of Interest

Flow along the 130-mile reach of the SJR from Mendota Dam to Vernalis is highly dependent on tributary inflows and the managed hydrology of the SJR system. Six reaches of the SJR with different flow regimes are readily identifiable. A single site within each reach will be used to assess the flows within each reach. Reaches and sites are shown in Table 4.1. Flow records compiled for the six sites will be used to calculate assimilative capacity for eight subareas of the SJR Basin that contribute flow to these reaches as shown in Table 4.2. The subareas are explained in more detail in appendix E of the *Lower San Joaquin River Basin Diazinon and Chlorpyrifos Source Analysis report* (Leva *et al*., 2002, draft).

Table 4.1 Monitoring Sites and River Reaches

River Sites	River Reach
Sack	Mendota Dam to Sack Dam
Lander	Sack Dam to Lander Avenue (Highway 165)
Upstream of Merced	Lander Avenue to Merced River Confluence
Patterson	Merced River Confluence to Tuolumne River Confluence
Maze	Tuolumne River Confluence to Stanislaus River Confluence
Vernalis	Stanislaus River Confluence to Vernalis

As shown in the source analysis section, there are two seasons of use for diazinon and chlorpyrifos: irrigation season from March through August, and the dormant spray season in January and February. Each season is considered separately in this analysis. So that only flow conditions similar to those anticipated under the current level of development are considered in the analysis, only the flow and precipitation record from 1980 through 2001 was used. As will be shown, design flow and loading capacity are not very sensitive to the length of the record since the large number of low flow conditions in the 21-year record used is the limiting factor.

Table 4.2 Watersheds Represented by Six Monitoring Sites Along Mainstem SJR

Subarea	Monitoring Sites					
	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack
Upstream of Sack Dam[1]	X	X	X	X	X	X
Upstream of Salt Slough[2]	X	X	X	X	X	
Grassland	X	X	X	X		
East Valley Floor	X	X	X			
Northwest	X	X	X			
Merced	X	X	X			
Tuolumne	X	X				
Stanislaus	X					

[1] Sack Dam
[2] Effective Drainage Area of San Joaquin River upstream of Salt Slough

Selection of Triggering Storm Event and Flow Averaging Period

Storm events were defined as the day that a minimum depth of precipitation fell and a specified number of days following the precipitation event. Depending on hydrology, it can take 2, 3, 4 days or more for runoff generated by precipitation to be routed to a given site. A downstream sites will generally have a longer collection period for rainfall runoff than an upstream sites because it has a larger drainage area. A maximum four-day collection period was considered because the critical low flow periods upon which a design flow must be based, occur during the rising limb of a storm hydrograph.

The acute and chronic CDFG criteria for diazinon and chlorpyrifos were used as the numeric targets for this analysis. Daily average flow was used to represent the flow for the one-hour average acute criteria. Four day average flows were used for the chronic criteria. The allowable excursion rate or frequency with which these criteria may be exceeded is once every three years.

Assemble and Process Rainfall and Flow Data

Raw precipitation and flow data for various reaches was assembled and processed for this analysis. The processing necessary to assemble a complete flow record for all river sites and a complete precipitation record for all basins that drain to a particular reach is described below.

Flow

The flow record for sites along six SJR reaches for the most recent 21-year period from 1980 through 2001 was assembled using data from the USGS and DWR. The most recent year, 2001, was supplemented with data from CDEC (CDEC, 2002). Only this 21-year period was used to characterize the flow record because it is most representative of the lower SJR at the current level of development. The flow record for seven sites was assembled to construct a 21-year flow record for six sites within six SJR reaches (Table 4.3). Actual flow data was used for Vernalis, Patterson, and Lander Avenue but a full record of flow data is unavailable for Maze Road, the SJR upstream of the Merced River confluence, and Sack Dam. Flow data for these sites was calculated using flow data from other stations:

SJR at Maze = SJR at Vernalis - Stanislaus River at Ripon
SJR Upstream of Merced = SJR at Lander Avenue + Salt Slough + Mud Slough
SJR at Sack Dam = SJR at Mendota Dam

Table 4.3 Period of record for flow stations used in this Total Maximum Daily Load

Site	USGS	DWR	CDEC
SJR near Vernalis	1980-2000	---	2001
Stanislaus near Ripon	1980-2000	---	2001
SJR near Patterson	---	1980-2001	---
Salt Slough near Lander	1985-2000	1980-1985	---
Mud Slough near Gustine	1985-2000	---	---
SJR near Lander	---	1980-2001	---
SJR at Mendota Dam	---	---	1993-2002
USGS: United States Geological Survey DWR: Department of Water Resources CDEC: California Data Exchange Center			

Precipitation
Precipitation in the basin occurs primarily during the winter months. Daily precipitation data from several sources was compiled from the UCIPM database. Table 4.4 provides information for each of the stations, including their location and the range of dates for which data is available. Sites were grouped based on location (Table 4.5) and a simple average rainfall was calculated for each subarea (Figure 4.1). The Thiessen polygon method was used to weight precipitation for each subarea and calculate their relative contribution to specific reaches of the SJR. The weighting coefficients used are shown in Table 4.6.

<u>Select and process flows that occur during time periods of interest</u>
Four-day average flows were next calculated using the constructed record of average daily flows for the six reaches of the SJR. The equation for calculating the four-day average flow on "n"th day of the month is:

$$Four\text{ - }Day\ Average\ Flow = \frac{\sum_{i=0}^{3} Q_{n+i}}{4}$$

This forward looking average is used so that the rainfall-runoff response is considered in the flow estimate. For example on the 3rd day of the month the calculated four-day average flow would be based on an average of the flow on the 3rd through 6th day of the month.

Data was next divided into two subsets, one for each season of pesticide use: dormant season and irrigation season. The dormant season is comprised of flow and precipitation data for December through February. Since rainfall-runoff is the primary method of pesticide movement in the dormant season, the dataset was filtered to pick out only those flows that followed storm events. Only the flow regimes following a storm event were considered for the flow record used to estimate design flows for the dormant season. The irrigation season is comprised of flow data for March through November. Since there is no rainfall runoff response to be considered for the irrigation season, all flows were considered to estimate design flows.

Dormant season monitoring in the SJR Basin has shown that peak concentrations and loads occur within two to four days or more after rainfall events of at least 0.25 to 0.50 inches. This lag is a function of both rainfall-runoff response time in the basin and travel time in the river. Subsets of the total dormant season flow record were therefore constructed of daily and four-day average flows for two, three, and four days following rainfall events of 0.25 to 0.50 inches. Additional number of lagged days were not considered since either: most pesticide movement will have already occurred in upstream sites and; only higher flows occur after 4 days at downstream sites with larger drainage areas. Addition of higher flow days will have no effect on the selection of design flows.

Combinations of the precipitation trigger values and the rainfall runoff response times results in six categories for both acute and chronic design flows during the dormant season.

Table 4.4 Precipitation stations for the lower San Joaquin River basin

Site	Operator	Start Date	End Date	Latitude	Longitude
atwater.t	---	8/8/1981	3/26/1987	37 21	120 40
ballico.t	Touchtone #51	4/1/1990	10/11/2001	37 28	120 45
cortez.t	Touchtone #04	5/4/1983	4/30/1995	37 29	120 42
cressey.t	Touchtone #41	2/1/1988	3/18/2002	37 24	120 40
denair.c	[2]NCDC #2389	1/14/1951	6/30/1984	37 34	120 47
denair.t	Touchtone #45	7/15/1989	1/15/2001	37 35	120 48
kestersn.a	[3]CIMIS #92	10/13/1989	3/25/2002	37 14	120 53
losbanos.a	CIMIS #56	7/1/1988	3/25/2002	37 06	120 46
losbanos.c	NCDC	4/1/1953	11/30/2001	37 03	120 52
losbanos.t	Touchtone #30	3/1/1981	8/10/1998	37 03	120 52
mdesto.c	NCDC #5738	3/3/1952	11/30/2001	37 39	121 00
merced.a	CIMIS #148	1/10/1999	1/1/2002	37 19	120 23
merced.c	NCDC #5532	1/20/1951	11/30/2001	37 17	120 31
modesto.a	CIMIS #71	6/25/1987	3/25/2002	37 38	121 11
newman.c	NCDC #6168	2/3/1951	11/30/2001	37 18	121 02
Patterson.a	CIMIS #161	1/13/2000	3/25/2002	37 26	121 08
pattrson.t	---	7/27/1981	4/1/1985	37 28	121 07

[1] Source: UCIPM, http://www.ipm.ucdavis.edu/WEATHER/weather1.html
[2] NCDC = National Climate Data Center
[3] CIMIS = California Irrigation Management Information System

Table 4.5 Grouping of precipitation stations

Grouping	Northwest	Northeast	Southwest	Southeast
Symbol	NW	NE	SW	SE
Stations	newman.c patterson.a patterson.t	denair.c denair.t mdesto.c modesto.a watrford.t	kestersn.a losbanos.a losbanos.c losbanos.t	atwater.t merced.a merced.c ballico.t

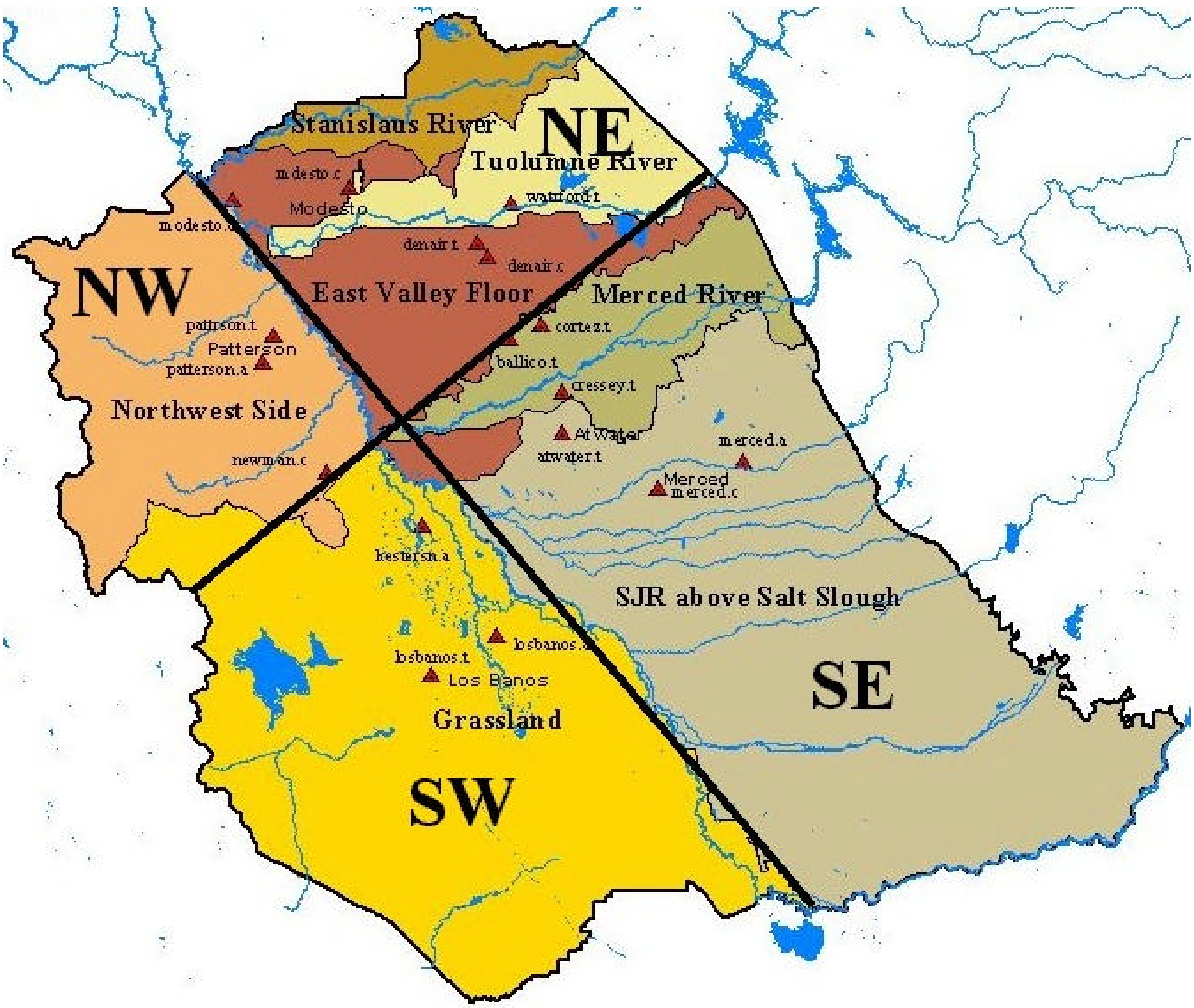


Figure 4.1 Grouping of precipitation stations.

Table 4.6 Rainfall Weighting

Station	Thiessen Equation	Subareas Represented
Vernalis	(0.25*NW)+(0.25*NE)+(0.25*SW)+(0.25*SE)	All
Maze	(0.25*NW)+(0.25*NE)+(0.25*SW)+(0.25*SE)	All w/o Stanislaus
Patterson	(0.15*NW)+(0.15*NE)+(0.35*SW)+(0.35*SE)	All w/o Stanislaus & Tuolumne
Upstream of Merced	(0*NW)+(0*NE)+(0.50*SW)+(0.50*SE)	All w/o Stanislaus, Tuolumne, Merced, Northwest Side
Lander	(0*NW)+(0*NE)+(0*SW)+(1.00*SE)	Upstream of Salt Slough
Sack	(0*NW)+(0*NE)+(0*SW)+(1.00*SE)	Upstream of Salt Slough

Select Design Flows

Once the flow records for the period of interest have been assembled, the daily flow and four-day average flow for each season (irrigation and dormant) and category were rank ordered from lowest to highest so that the appropriate low flow condition or design flow could be selected. Both the acute and chronic CDFG criteria for diazinon and chlorpyrifos specify an allowable one in three year rate of excursion of the numeric concentration. This excursion rate is used to identify the design flow with the appropriate anticipated rate of return. For a given period of record and allowable frequency of excursions, the allowable number of excursions was calculated using:

$$\textit{Allowable Number of Excursions} = \textit{Period of Record} \times \textit{Allowable Frequency of Excursion}$$

There are 7 allowable excursions for a one in three year excursion frequency over the 22-year flow record under consideration. The design flow is the 7th lowest flow of the rank ordered flows assembled for a given scenario (e.g. acute criteria for diazinon during the dormant season). The design flow multiplied by the water quality objective is the allowable load. If flows occur lower than the design flow, the water quality objective would be exceeded. To avoid a disproportionate effect of consecutive days of low flow in a single year, the U.S. EPA method suggests that the number of excursions be limited to five during any 120-day period. If there were more than five low flows in a single season (dormant or irrigation), the lowest flows in excess of five were removed from the flow record for that season. Summary results of design flows for the acute and chronic criteria (daily average and four-day average flows, respectively) for both the dormant and irrigation seasons are given in Table 4.7. Design flows for the six categories of rainfall and collection period (0.25 and 0.50 inches of rain with two, three, and four days of rainfall-runoff response times) are presented for both the acute and chronic criteria during the dormant season. Design flows for all these permutations are shown for the six sites selected to represent design flows for six reaches of the SJR.

Inspection of design flows presented in Table 4.7 shows that for a given site, design flow depends on the rainfall threshold and collection period. Most of the variability is attributable to the rainfall threshold, with higher design flows for the 0.5-inch rainfall than for the 0.25-inch rainfall. Since both the acute and chronic criteria in the SJR have been exceeded following rainfall events of 0.25 and 0.50 inches and within 2 to 4 days following a rainfall event, the lowest design flows were selected for each site (Table 4.8). As explained in the next section, this provides an implicit margin of safety for the load allocations. Design flows for the upstream reaches of the SJR are very low for some categories. This finding is consistent with the prolonged periods of extremely low flow or no flow observed for these reaches.

Table 4.7 Range of Design Flows Calculated For Six Reaches of San Joaquin River with a 1 in 3 year Excursion Rate

Season	Criteria	Category	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack
		Rainfall (in) and Days	Design Flow[1] (cfs)					
Dormant	Acute	[2]0.25&2d	946	741	321	82	1	63
		0.25&3d	924	741	321	82	1	62
		0.25&4d	910	737	321	80	1	62
		0.50&2d	1400	1019	493	166	3	94
		0.50&3d	1400	1019	493	166	3	65
		0.50&4d	1400	1019	493	156	3	64
	Chronic	0.25&2d	903	734	350	88	1	63
		0.25&3d	903	734	350	88	1	62
		0.25&4d	903	734	350	87	1	62
		0.50&2d	1655	1274	697	137	2	82
		0.50&3d	1605	1274	691	132	2	80
		0.50&4d	1590	1274	637	126	2	72
Irrigation	Acute		413	446	173	167	10	1
	Chronic		428	481	186	179	10	1

[1]Design flows based upon 7th lowest flow in 22-year flow record (1 in 3 year excursion)

[2]Daily flow if precipitation exceeded 0.25" in any prior 2 days

Table 4.8 Design Flows For Six Reaches of San Joaquin River with a 1 in 3 year Excursion Rate

Season/Criteria	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack
Dormant	Design Flow[1] (cfs)					
Acute[2]	946	741	321	82	1	63
Chronic[3]	903	734	350	166	1	63
Irrigation						
Acute	446	173	164	10	1	20
Chronic	481	186	179	10	1	21

[1]Design flows based upon 7th lowest flow in 22-year flow record (1 in 3 year excursion)

[2]Design flows for acute criteria are mean daily flows

[3]Design flows for chronic criteria are four-day average flows

Calculate the total allowable load

The TMDL is the full assimilative capacity of the water body. The assimilative capacity (in pounds) was calculated by multiplying the design flows in Table 4.8 (in cfs) by the water quality objective (in ì g/L) and applying a conversion factor of 0.0054 to account for unit conversions:

$$TMDL\ (pounds) = Q_{DF}(cfs) \times WQO\ (\mu g/L) \times 0.0054\ (conversion\ \ factor)$$

The matrix of allowable loads for the dormant and irrigation season, based on both the acute and chronic criteria are shown for the six SJR reaches in Tables 4.9 and 4.10 for diazinon and chlorpyrifos, respectively.

Table 4.9 Allowable Diazinon Loads For Six Reaches of San Joaquin River with a 1 in 3 year Excursion Rate

Season/Criteria	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack
Dormant	----------------------------- pounds/day ----------------------------					
Acute[2]	0.409	0.320	0.139	0.035	0.000	0.027
Chronic[3]	0.244	0.198	0.095	0.024	0.000	0.017
Irrigation						
Acute	0.193	0.075	0.071	0.004	0.000	0.009
Chronic	0.130	0.050	0.048	0.003	0.000	0.006
Design flows based upon 7th lowest flow in 22-year flow record (1 in 3 year excursion)						
[2] Mean daily loads for acute criteria						
[3] Four-day average loads for chronic criteria						

Table 4.10 Allowable Chlorpyrifos Loads For Six Reaches of San Joaquin River with a 1 in 3 year Excursion Rate

Season/Criteria	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack
Dormant	----------------------------- pounds/day ----------------------------					
Acute[2]	0.128	0.100	0.043	0.011	0.000	0.009
Chronic[3]	0.068	0.055	0.026	0.007	0.000	0.005
Irrigation						
Acute	0.060	0.023	0.022	0.001	0.000	0.003
Chronic	0.036	0.014	0.014	0.001	0.000	0.002
Design flows based upon 7th lowest flow in 22-year flow record (1 in 3 year excursion)						
[2] Mean daily loads for acute criteria						
[3] Four-day average loads for chronic criteria						

4.4 Considerations

To further assess these allowable loads, additional consideration was given to:

- Sufficiency of the flow record
- Additive toxicity
- Seasonality

The flow record was examined to assure that a record of sufficient length was used in the determination of design flows. Allowable loads presented in Tables 4.9 and 4.10 also do not yet consider that the pesticides have additive toxic effects and that there are two seasons of use.

Sufficiency of the flow record

Design flows for this TMDL are based upon only the most recent 22-year record from 1980 through 2001. Although flow data is available for a longer time period in the SJR Basin, the data was not used because there have been major changes in LSJR hydrology. The most significant change is completion of New Melones Reservoir in 1979; the additional storage provided by this reservoir has changed the pattern of flows in the river. Only the last 21 years is therefore representative of the current level of development of the SJR Basin. This period also contains some of the most critically low flow conditions on record. It is these critically low flow years that have the greatest influence on the determination of design flows because they are skewed towards low flows (figure 4.2). The design flow (the 7th lowest flow for the 22-years) is 846 cfs based on all flow records. To assess the effect of a longer and wetter flow record, the 22-year record was appended with additional wet flows (figure 4.3). The design flow for this constructed dataset is 910 cfs (the 14th lowest flow for the 42-years of data). Addition of 22 years of higher flows does not substantially change the low flow condition because the actual flow record is skewed so strongly towards low flows.

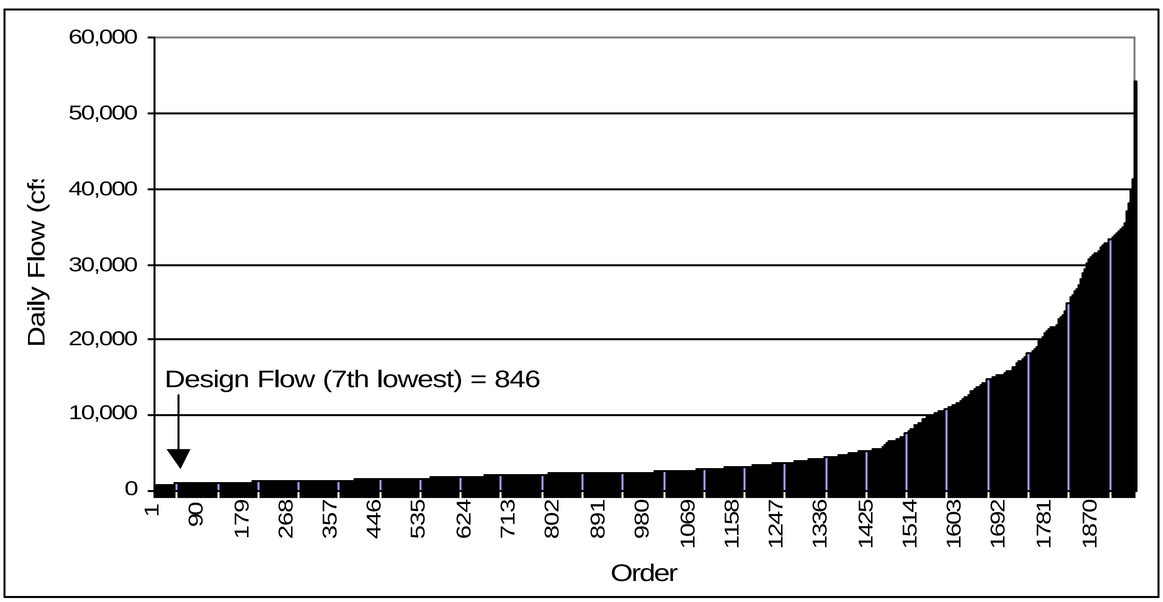


Figure 4.2 Vernalis Design Flows for Dormant Season

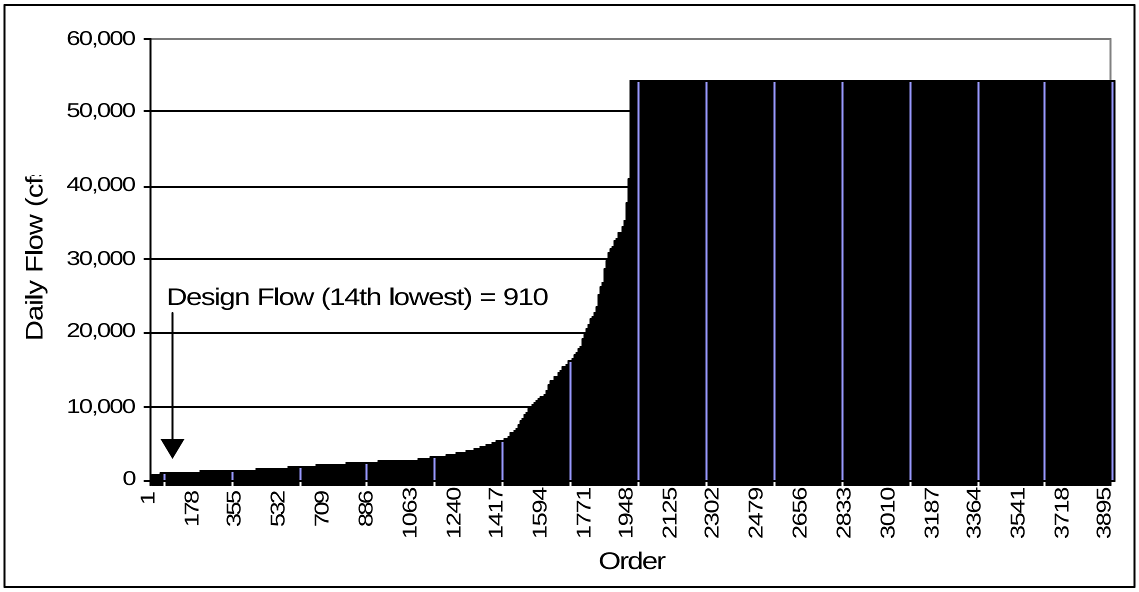


Figure 4.3 Vernalis Design Flows for Dormant Season With Added High Flows

Additive Toxicity

The individual allowable loads limits for diazinon and chlorpyrifos must not be exceeded in order to meet the individual TMDL numeric targets for diazinon and chlorpyrifos. The additive toxic effect of these pesticides requires that individual load limit for each pesticide is reduced to account for the presence of the other pesticide. The total load allocation was assessed using a method similar to that used to assess the additive toxic effects of concentrations for multiple pollutants that have similar toxicological mechanisms:

$$\sum_{i=1}^{n} \frac{\text{measured load of pollutant}_{\text{i}}}{\text{allowable load of pollutant}_{\text{i}}} < 1.0$$

Applied to diazinon and chlorpyrifos allowable loads, the individual load allocations for each was reduced so that the cumulative allowable load is less than 100 percent of the cumulative additive load:

$$\text{Cumulative Additive Load} = \frac{\text{measured load of diazinon}}{\text{allowable load of diazinon}} + \frac{\text{measured load of chlorpyrif os}}{\text{allowable load of chlorpyrif os}} < 1.0$$

For example, the diazinon and chlorpyrifos acute load limits in the SJR near Vernalis in the dormant season are 0.409 and 0.128 pounds respectively. If the measured load of diazinon in 0.245 pounds, or 60 percent of the allowable load, a maximum of 40 percent, or 0.051 pounds, of chlorpyrifos allowable load is available.

<u>Seasonality</u>

There are two seasons of use for both diazinon and chlorpyrifos. The allowable loads presented in tables 4.9 and 4.10 assume only one season of use with all possible excursions of the numeric criteria occurring within one season. To account for the two seasons of use, the methods presented above were modified to allow for only a one in six year excursion rate for each season. This results in a net excursion rate of one in three years for both seasons. Design flows obtained for a one in six year excursion rate are shown in Tables 4.11 and 4.12. Total allowable loads for diazinon and chlorpyrifos are shown in Tables 4.13 and 4.14, respectively.

Table 4.11 Range of Design Flows Calculated For Six Reaches of San Joaquin River with a 1 in 6 year Excursion Rate

Season	Criteria	Category	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack
		Rainfall (in) and Days	------------------------- Design Flow[1] (cfs) ---------------------------------					
Dormant	Acute	[2]0.25&2d	740	547	282	70	0	61
		0.25&3d	740	547	282	70	0	61
		0.25&4d	740	547	282	70	0	59
		0.50&2d	946	741	374	108	0	61
		0.50&3d	946	741	374	108	0	61
		0.50&4d	946	741	374	108	0	61
	Chronic	0.25&2d	880	700	325	71	0	62
		0.25&3d	877	697	325	67	0	61
		0.25&4d	873	683	325	64	0	59
		0.50&2d	1001	790	413	127	0	65
		0.50&3d	1001	790	413	124	0	65
		0.50&4d	990	790	413	124	0	65
Irrigation	Acute		405	147	145	6	0	12
	Chronic		421	157	163	8	0	19

[1]Design flows based upon 3rd lowest flow in 22-year flow record (1 in 6 year excursion)

[2]Daily flow if precipitation exceeded 0.25" in any prior 2 days

Table 4.12 Design Flows For Six Reaches of San Joaquin River with a 1 in 6 year Excursion Rate

Season/Criteria	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack
Dormant	--------------------- Design Flow[1] (cfs) ----------------------------					
Acute[2]	740	547	282	70	0	59
Chronic[3]	873	683	325	64	0	59
Irrigation						
Acute	405	147	145	6	0	12
Chronic	421	157	163	8	0	19

Design flows based upon 3rd lowest flow in 22-year flow record (1 in 6 year excursion)

[2]Design flows for acute criteria are mean daily flows

[3]Design flows for chronic criteria are four-day average flows

Table 4.13 Allowable Diazinon Loads For Six Reaches of San Joaquin River with a 1 in 6 year Excursion Rate

Season/Criteria	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack
Dormant	------------------------------ pounds/day ----------------------------					
Acute[2]	0.320	0.236	0.122	0.030	0.000	0.026
Chronic[3]	0.238	0.189	0.088	0.019	0.000	0.017
Irrigation						
Acute	0.175	0.064	0.063	0.003	0.000	0.005
Chronic	0.114	0.042	0.044	0.002	0.000	0.005

Design flows based upon 3rd lowest flow in 22-year flow record (1 in 6 year excursion)

[2]Allowable loads for acute criteria are daily loads

[3]Allowable loads for chronic criteria are four-day average loads

Table 4.14 Allowable Chlorpyrifos Loads For Six Reaches of San Joaquin River with a 1 in 6 year Excursion Rate

Season/Criteria	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack
Dormant	------------------------------ pounds/day ----------------------------					
Acute[2]	0.100	0.074	0.038	0.009	0.000	0.008
Chronic[3]	0.067	0.053	0.025	0.005	0.000	0.005
Irrigation						
Acute	0.055	0.020	0.020	0.001	0.000	0.002
Chronic	0.032	0.012	0.012	0.001	0.000	0.001

Design flows based upon 3rd lowest flow in 22-year flow record (1 in 6 year excursion)

[2]Allowable loads for acute criteria are daily loads

[3]Allowable loads for chronic criteria are four-day average loads

4.5 Results

The linkage analysis provides the total assimilative capacity for diazinon and chlorpyrifos in various reaches of the SJR during both the irrigation and dormant spray season based on both the acute and chronic criteria. The total allowable load for each season of use depends on whether or not the rate of excursion is considered separately or cumulatively. Selection of the appropriate method of allocating load will depend upon the methods of implementation pursued for achieving load reductions. The next step in the analysis is to allocate the total assimilative capacity to various sources in the basin.

5.0 ALLOCATIONS

The purpose of the load allocation is to allocate portions of the assimilative capacity calculated in the linkage analysis to the known sources of diazinon and chlorpyrifos. TMDL load allocations are designed to result in attainment of the numeric target. They are established in this TMDL to meet water the numeric targets for diazinon and chlorpyrifos at six compliance points along the main stem SJR. Allocations presented here are based on the numeric targets and the source areas of pesticides in the lower SJR Basin.

The total assimilative capacity, or TMDL, must be distributed between a background load (BL), a margin of safety (MOS), a waste load allocation (WLA) for point sources, and a load allocation (LA) for non-point sources.

$$TMDL = BL + MOS + WLA + LA$$

5.1 Background Load

Although pesticides have been detected in rainfall, there is currently insufficient information to assign an explicit background loading term for this potential source. Future loading attributable to rainfall is included in the load allocation. No additional, explicit background loading of diazinon and chlorpyrifos is therefore used.

5.2 Margin of Safety

No consistent errors have been identified in the flow and pesticide water quality information used to generate this TMDL. No explicit margin of safety is therefore used to account for any such errors. Selection of the lowest design flows for the various scenarios explored in the linkage analysis provides an implicit margin of safety for the load allocations. No additional explicit margin of safety is therefore proposed for this TMDL.

5.3 Waste Load Allocation

Point sources include any concentrated discharge that can be controlled at a point, such as a municipal wastewater treatment plant. The source analysis has shown that the urban component to diazinon and chlorpyrifos loads in the SJR is relatively small. With the current phasing out of diazinon and chlorpyrifos for urban uses, the urban source is expected to decrease further. Because diazinon from agricultural sources can be present in rainfall in urban areas, the waste load allocation from municipal stormwater discharges is no detectable increase in the background of diazinon and chlorpyrifos already present in rainfall.

5.4 Load Allocation

With no background sources, no explicit margin of safety, or waste load allocation assigned in this TMDL, the entire TMDL, or allowable load may be allocated to non-point, agricultural sources. There are several load allocation scenarios that could be used to allocate loads to agricultural sources. Methods used to allocate loads could be based upon a geographic split, crop or land-use patterns, pesticide use, present loading rates, or a mix of these.

Load allocation scenarios without a geographic component were not considered because of the difficulty in measuring compliance with such a scenario. Scenarios based on current loading rates were not considered because this would disadvantage dischargers and areas that have already effectively minimized offsite movement of pesticides through implementation of management practices. In addition, insufficient information is available to characterize current loading rates from all areas. Scenarios based on pesticide use rates were also not considered since this may disadvantage areas and dischargers that try to minimize offsite movement of pesticide through reduced use. This leaves only two scenarios to consider:

- Geographic allocations of loads
- Geographic allocation of loads considering crops that use diazinon and chlorpyrifos.

For these or any other scenarios, the specific load allocations must also consider the point of discharge to the SJR. Under each scenario, an entity or area that discharges pesticides may get a disproportionately high or low allocation relative to their percent of acreage in a subarea or acreage of a crop because of the reach to which this entity discharges. Allowable load is ultimately controlled by the available flow (design flow) for the reach to which loading occurs. For example, 100 acres in areas that discharge to the SJR upstream of the Merced River will likely have a lower load allocation than 100 acres that discharge to a reach downstream of the Stanislaus River.

<u>Geographic allocation of loads</u>

Loads in this scenario are allocated only by subarea acreage. Acreage of each subarea is determined and calculated as a percent of the entire basinwide acreage (table 5.1). Allocations for each subarea are limited to the lowest allocations available, based on meeting targets in each of the six river reaches. Selection of the lowest allocation makes available additional loading capacity that can be redistributed to downstream subareas. This additional loading capacity is allocated to downstream subareas based on a prorated assessment of the acreage in these subareas. The sum of the final allocations remains equal to the total SJR near Vernalis load allocation (Table 5.2). These allocations assume a one in three year excursion rate of the objective for each season. Compliance with these load limits would therefore result in a one in three year excursion of the objective in each season, resulting in a total of two excursions every three years.

To account for the two seasons of use, allocations were also calculated for a one in six year excursion rate (Table 5.3). The methods used to redistribute load allocations between subareas was the same as that used for the one in three year excursion rate. As for total loading capacity, load allocations based on a one in three year excursion rate are lower than those for a one in three year excursion rate.

Table 5.1 Geographic Distribution of Subareas to Six Reaches of the lower San Joaquin River

Subarea	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack	Subarea Land Area	
	------------------------------- % -------------------------------						mi^2	
Upstream of Salt Slough[1]	14.3	15.0	16.1	27.8	100.0	100.0	523	523
Grassland	37.3	38.9	41.9	72.2			1,360	1,883
East Valley Floor	13.0	13.6	14.7				476	2,359
Northwest	16.5	17.2	18.6				603	2,962
Merced	7.7	8.0	8.7				281	3,243
Tuolumne	6.9	7.2					253	3,496
Stanislaus	4.2						152	3,648
Total	100.0	100.0	100.0	100.0	100.0	100.0		

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough

Table 5.2 Geographic Load Allocations for a 1 in 3 year Excursion Rate for Each Season

Subarea	Diazinon				Chlorpyrifos			
	Dormant		Irrigation		Dormant		Irrigation	
	Acute[2]	Chronic[3]	Acute	Chronic	Acute	Chronic	Acute	Chronic
	----------------------------------- pounds/day --------------------------------							
Upstream of Salt Slough[1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Grassland	0.035	0.024	0.004	0.003	0.011	0.007	0.001	0.001
East Valley Floor	0.101	0.059	0.051	0.034	0.032	0.016	0.016	0.009
Northwest	0.128	0.075	0.064	0.043	0.040	0.021	0.020	0.012
Merced	0.060	0.035	0.030	0.020	0.019	0.010	0.009	0.006
Tuolumne	0.054	0.032	0.027	0.018	0.017	0.009	0.008	0.005
Stanislaus	0.032	0.019	0.018	0.012	0.010	0.005	0.005	0.003
Vernalis LA	0.409	0.244	0.193	0.130	0.128	0.068	0.060	0.036

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough
[2] Loads for acute criteria are daily loads
[3] Loads for chronic criteria are four-day average loads

Geographic allocation of loads considering crops that use diazinon and chlorpyrifos

A purely geographic allocation of loads does not consider that crops more likely to use diazinon and chlorpyrifos may not be evenly distributed in the basin. This scenario weights the load allocations according to crops that typically use diazinon and chlorpyrifos. To perform this weighting, the five crops that use the most pesticide for the given pesticide and season were identified (Table 5.4). The highest diazinon use crops in the dormant season are almonds, peaches/nectarines, apricots, plums/prunes, and apples. The highest diazinon use crops in the irrigation season are almonds, melons, apricots, walnuts, and plums/prunes. The highest chlorpyrifos use crops in the dormant season are alfalfa, almonds, apples, table grapes, and peaches/nectarines. The highest chlorpyrifos use crops in the irrigation season are almonds, walnuts, cotton, alfalfa, and corn. The sum of acreage of the top five diazinon use crops for each subarea during the dormant season is shown in table 5.5. The percent contribution of these top five diazinon use crop acreages from each subarea along six reaches of the LSJR for diazinon during the dormant season is shown in table 5.6. The sum of acreage of the top five diazinon use crops for each subarea during the irrigation season is shown in table 5.7. The percent contribution of these top five diazinon use crop acreages from each subarea along six reaches of the LSJR for diazinon during the irrigation season is shown in table 5.8[5].

The sum of acreage of the top five chlorpyrifos use crops for each subarea during the dormant season is shown in table 5.9. Percent contribution of these top five chlorpyrifos use crop acreages from each subarea along six reaches of the LSJR for chlorpyrifos during the dormant season is shown in table 5.10. The sum of acreage of the top five chlorpyrifos use crops for each subarea during the irrigation season is shown in table 5.11. Percent contribution of these top five chlorpyrifos use crop acreages from each subarea along six reaches of the LSJR for chlorpyrifos during the irrigation season is shown in table 5.12.

Table 5.3 Geographic Load Allocations for a 1 in 6 year Excursion Rate

Subarea	Diazinon				Chlorpyrifos			
	Dormant		Irrigation		Dormant		Irrigation	
	Acute[2]	Chronic[3]	Acute	Chronic	Acute	Chronic	Acute	Chronic
	---------------------------------- pounds/day --------------------------------							
Upstream of Salt Slough[1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Grassland	0.030	0.019	0.003	0.002	0.009	0.005	0.001	0.001
East Valley Floor	0.078	0.059	0.046	0.030	0.025	0.017	0.014	0.008
Northwest	0.099	0.075	0.058	0.038	0.031	0.021	0.018	0.010
Merced	0.046	0.035	0.027	0.018	0.014	0.010	0.009	0.005
Tuolumne	0.042	0.031	0.024	0.016	0.013	0.009	0.008	0.005
Stanislaus	0.025	0.019	0.016	0.011	0.008	0.005	0.005	0.003
Vernalis LA	0.320	0.238	0.175	0.114	0.100	0.067	0.055	0.032

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough
[2] Loads for acute criteria are daily loads
[3] Loads for chronic criteria are four-day average loads

[5]The top 5 crops for diazinon in the irrigation season include melons; at the time of this evaluation, melon acreage was unavailable and prunes were used as the fifth crop.

Table 5.4 Seasonal Pesticide use of Diazinon and Chlorpyrifos for the Top 15 Crops

Crop	Diazinon				Chlorpyrifos			
	Dormant		Irrigation		Dormant		Irrigation	
	Total lbs AI	Percent	Total lbs AI	Percent	Total lbs AI	Percent	Total lbs AI	Percent
Alfalfa	1,078	2.42	10	0.06	20,645	56.85	10,914	7.43
Almond	27,745	62.16	4,026	27.33	6,765	18.63	63,858	43.45
Apple	2,292	5.14	230	1.56	3,629	9.99	4,482	3.05
Apricot	3,116	6.98	1,303	8.84	0	0.00	999	0.68
Cantaloupe	0	0.00	2,308	15.66	27	0.07	64	0.04
Cherry	426	0.95	155	1.05	0	0.00	713	0.49
Grapes (wine)	68	0.15	11	0.07	79	0.22	9,321	6.34
Melons/Squash/Cucumber	0	0.00	1,562	10.60	9	0.02	23,405	15.92
Nectarine	1,180	2.64	150	1.02	2,266	6.24	0	0.00
Peach	5,451	12.21	399	2.71	400	1.10	49	0.03
Plum and Prune	2,776	6.22	1,114	7.55	1,53	3.73	54	0.03
Tomatoes (processing)	193	0.43	991	6.73	0	0.00	3,372	2.29
Walnut (english, persian)	15	0.03	1,285	8.72	387	1.07	2,615	1.78
Watermelons	10	0.02	238	1.62	1	0.00	26,517	18.04
Other	286	0.64	953	6.47	751	2.07	616	0.42
Total	44,636	100	14,734	100	36,312	100	146,979	100
lbs AI = pounds active ingredient								

Table 5.5 Sum of Acreage of Top Five Diazinon Use Crops for Each Subarea During the Dormant Season

Subarea	Almond	Peach/Nectarine	Apricot	Apple	Prune	Total
	------------------------------- acres -------------------------------					
Upstream of Salt Slough[1]	28,465	2,022	86	105	333	31,011
Grassland	5,664	94	2,027	176	998	8,959
East Valley Floor	59,568	5,393	138	1,044	0	66,143
Northwest Side	12,446	176	9,280	178	0	22,080
Merced	46,298	4,354	277	2,184	172	53,285
Tuolumne	13,437	2,433	59	324	0	16,253
Stanislaus	11,549	2,199	39	185	0	13,972
Total	177,427	16,671	11,906	4,196	1,503	211,703
[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough						

Table 5.6 Contribution of Top Five Crop Acreages for Each Subarea Along Six Reaches of the LSJR for Diazinon During the Dormant Season

Subarea	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack	Crop Land Area (acres)	
	--------------------------------- %					---------------------------------	subarea	total
Upstream of Salt Slough[1]	14.6	15.7	17.1	77.6	100.0	100.0	31,011	31,011
Grassland	4.2	4.5	4.9	22.4			8,959	39,970
East Valley Floor	31.2	33.5	36.4				66,143	106,113
Northwest	10.4	11.2	12.2				22,080	128,193
Merced	25.2	26.9	29.4				53,285	181,478
Tuolumne	7.7	8.2					16,253	197,731
Stanislaus	6.6						13,972	211,703
Total	100	100	100	100	100	100		

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough

Table 5.7 Sum of Acreage of Top Five Diazinon Use Crops for Each Subarea During the Irrigation Season

Subarea	Almond	Melons	Apricot	Walnut	Prunes	Total
	--------------------------------- acres					---------------------------------
Upstream of Salt Slough[1]	28,465	1,001	86	1,549	333	31,434
Grassland	5,664	23,819	2,027	2,332	998	34,840
East Valley Floor	59,568	893	138	7,337	0	67,936
Northwest Side	12,446	6,061	9,280	8,441	0	36,228
Merced	46,298	302	277	1,500	172	48,549
Tuolumne	13,437	214	59	6,527	0	20,237
Stanislaus	11,549	12	39	7,448	0	19,048
Total	177,427	32,302	11,906	35,134	1,503	258,272

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough

Table 5.8 Contribution of Top Five Crop Acreages for Each Subarea Along Six Reaches of the LSJR for Diazinon During the Irrigation Season

Subarea	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack	Crop Land Area	
	--------------------------------- %					---------------------------------	subarea	total
Upstream of Salt Slough[1]	12.2	13.1	14.4	47.4	100.0	100.0	31,434	31,434
Grassland	13.5	14.6	15.9	52.6			34,840	66,274
East Valley Floor	26.3	28.4	31.0				67,936	134,210
Northwest	14.0	15.1	16.5				36,228	170,438
Merced	18.8	20.3	22.2				48,549	218,987
Tuolumne	7.8	8.5					20,237	239,224
Stanislaus	7.4						19,048	258,272
Total	100	100	100	100	100	100		

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough

Table 5.9 Sum of Acreage of Top Chlorpyrifos Use Crops for Each Subarea During the Dormant Season

Subarea	Alfalfa	Almond	Apple	Grapes (table)	Peach/ Nectarine	Total
	------------------------------ acres ------------------------------					
Upstream of Salt Slough[1]	14,846	28,465	105	4,040	2,022	49,478
Grassland	58,154	5,664	176	1,821	94	65,909
East Valley Floor	22,555	59,568	1,044	10,458	5,393	99,018
Northwest Side	17,921	12,446	178	169	176	30,890
Merced	4,343	46,298	2,184	13,407	4,354	70,586
Tuolumne	521	13,437	324	1,842	2,433	18,557
Stanislaus	458	11,549	185	2,078	2,199	16,469
Total	118,798	177,427	4,196	33,815	16,671	350,907

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough

Table 5.10 Contribution of Top Five Crop Acreages for Each Subarea Along Six Reaches of the LSJR for Chlorpyrifos During the Dormant Season

Subarea	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack	Crop Land Area	
	------------------------------ % ------------------------------						subarea	total
Upstream of Salt Slough[1]	14.1	14.8	15.7	42.9	100.0	100.0	49,478	49,478
Grassland	18.8	19.7	20.9	57.1			65,909	115,387
East Valley Floor	28.2	29.6	31.3				99,018	214,405
Northwest	8.8	9.2	9.8				30,890	245,295
Merced	20.1	21.1	22.3				70,586	315,881
Tuolumne	5.3	5.5					18,557	334,438
Stanislaus	4.7						16,469	350,907
Total	100	100	100	100	100	100		

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough

Table 5.11 Sum of Acreage of Top Chlorpyrifos Use Crops for Each Subarea During the Irrigation Season

Subarea	Almond	Walnut	Cotton	Alfalfa	Corn	Total
	------------------------------ acres ------------------------------					
Upstream of Salt Slough[1]	28,465	1,549	12,412	14,846	15,983	73,255
Grassland	5,664	2,332	138,009	58,154	14,162	218,321
East Valley Floor	59,568	7,337	0	22,555	49,239	138,699
Northwest Side	12,446	8,441	269	17,921	5,112	44,189
Merced	46,298	1,500	0	4,343	9,905	62,046
Tuolumne	13,437	6,527	0	521	6,608	27,093
Stanislaus	11,549	7,448	0	458	3,861	23,316
Total	177,427	150,690	35,134	118,798	104,870	586,919

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough

Table 5.12 Contribution of Top Five Crop Acreages for Each Subarea Along Six Reaches of the LSJR for Chlorpyrifos During the Irrigation Season

Subarea	Vernalis	Maze	Patterson	Upstream of Merced	Lander	Sack	Crop Land Area	
	---------- % ----------						subarea	total
Upstream of Salt Slough[1]	12.5	13.0	13.7	25.1	100.0	100.0	73,255	73,255
Grassland	37.2	38.7	40.7	74.9			218,321	291,576
East Valley Floor	23.6	24.6	25.9				138,699	430,275
Northwest	7.5	7.8	8.2				44,189	474,464
Merced	10.6	11.0	11.6				62,046	536,510
Tuolumne	4.6	4.8					27,093	563,603
Stanislaus	4.0						23,316	586,919
Total	100	100	100	100	100	100		

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough

Table 5.13 Load Allocations according to a cropland use within subarea allocation scheme with a 1 in 3 year Excursion Rate for Each Season

Subarea	Diazinon				Chlorpyrifos			
	Dormant		Irrigation		Dormant		Irrigation	
	Acute[2]	Chronic[3]	Acute	Chronic	Acute	Chronic	Acute	Chronic
	---------- pounds/day ----------							
Upstream of Salt Slough[1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Grassland	0.007	0.006	0.004	0.003	0.009	0.005	0.001	0.001
East Valley Floor	0.155	0.042	0.028	0.018	0.017	0.010	0.006	0.007
Northwest	0.052	0.014	0.015	0.010	0.005	0.003	0.002	0.008
Merced	0.125	0.034	0.020	0.013	0.012	0.007	0.003	0.011
Tuolumne	0.038	0.080	0.008	0.005	0.045	0.022	0.003	0.005
Stanislaus	0.033	0.069	0.118	0.080	0.040	0.020	0.046	0.004
Vernalis LA	0.409	0.244	0.193	0.130	0.128	0.068	0.060	0.036

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough
[2] Loads for acute criteria are daily loads
[3] Loads for chronic criteria are four-day average loads

The percent of pesticide use in each season for each subareas was then applied to the total loading capacity. As for the simple geographic allocations of loads, allocations for each subarea are limited to the lowest allocations available, based on meeting targets in each of the six river reaches. Selection of the lowest allocation makes available additional loading capacity that can be redistributed to downstream subareas. This additional loading capacity is allocated to downstream subareas based on a prorated assessment of the crop acreage in these subareas. The sum of the final allocations remains equal to the total SJR near Vernalis load allocation (Table 5.13). These allocations assume a one in three year excursion rate of the objective for each season. Compliance with these load limits would therefore result in a one in three year excursion of the objective in each season, resulting in a total of two excursions every three years.

To account for the two seasons of use, allocations were also calculated for a one in six year excursion rate (Table 5.14). The methods used to redistribute load allocations between subareas was the same as that used for the one in three year excursion rate. As for total loading capacity, load allocations based on a one in three year excursion rate are lower than those for a one in three year excursion rate.

Table 5.14 Load Allocations for Diazinon according to a cropland use within subarea allocation scheme, with a 1 in 6 year Excursion Rate

Subarea	Diazinon				Chlorpyrifos			
	Dormant		Irrigation		Dormant		Irrigation	
	Acute[2]	Chronic[3]	Acute	Chronic	Acute	Chronic	Acute	Chronic
	---------------------------------- pounds/day --------------------------------							
Upstream of Salt Slough[1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Grassland	0.006	0.005	0.003	0.002	0.008	0.005	0.001	0.001
East Valley Floor	0.121	0.039	0.026	0.017	0.015	0.010	0.005	0.006
Northwest	0.040	0.013	0.009	0.006	0.005	0.003	0.002	0.007
Merced	0.097	0.031	0.020	0.013	0.011	0.007	0.002	0.010
Tuolumne	0.030	0.081	0.007	0.004	0.033	0.022	0.003	0.004
Stanislaus	0.026	0.069	0.111	0.072	0.029	0.020	0.043	0.004
Vernalis LA	0.320	0.238	0.175	0.114	0.100	0.067	0.055	0.032

[1] Effective Drainage Area of San Joaquin River upstream of Salt Slough
[2] Loads for acute criteria are daily loads
[3] Loads for chronic criteria are four-day average loads

5.5 Summary

No waste load allocations are provided in this TMDL. The margin of safety is implicit in the conservative method used to calculate design flows. All allowable loads are allocated to agricultural nonpoint sources. Two methods have been presented to allocate loads: a purely geographic allocation, and a geographic allocation based on crop pesticide use. Load limits based on a single season and two seasons of use have been presented. All load limits presented represent the loading capacity for a single pesticide (diazinon or chlorpyrifos) that assumes the presence of only one of these pesticides. The final allocation for each pesticide must be reduced to account for the presence of the other. Selection of the appropriate load allocation scenario will depend on public feedback and additional information considered during the Basin Plan Amendment phase of this TMDL.

6.0 PUBLIC PARTICIPATION

Regional Board staff held public workshops to inform the public and interested parties of the status and staff progress on the diazinon and chlorpyrifos TMDL. The workshops included the initial outreach to inform the stakeholder that this TMDL was being started and continuous updates were conducted when each draft report component of the SJR Chlorpyrifos and Diazinon TMDL was completed. These workshops were held to seek public input during TMDL development. Table 6.1 shows the date and topics of the public workshops. Additional outreach were made to San Joaquin River Agricultural Implementation Group (AIG) and Merced and Stanislaus counties pest control advisors and pest control applicators to provide update status of the various elements of the TMDL.

Table 6.1 Summary of Public Workshop – San Joaquin River Diazinon and Chlorpyrifos TMDL

Date	Workshop
August 2000	Initial Outreach of OP Pesticide TMDL
November 2000	Initial Stage of the TMDL Development / Draft Problem Statement
January 2001	Introduced Elements of TMDL and Monitoring Data
June 2001	Draft Numeric Target Report
March 2002	Draft Source Analysis Report
July 23, 2002	Draft TMDL Report and Implementation Framework

A staff workshop will be held on 23 July 2002 at which members of the public will have the opportunity to discuss the draft TMDL Report and the Implementation Framework with Regional Board staff. Additional workshops will be held during the Basin Planning phase. The Regional Board will consider adoption of the proposed Basin Plan amendment during a public hearing. Regional Board staff anticipates proposing a Basin Plan Amendment to the Regional Board by June 2003.

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